

# jurnalprimed@uniramalang.ac.id 1

## Yulia.pdf

 Library - No Repository 15

 Library A

 Rct.tech1222

---

### Document Details

**Submission ID**

trn:oid::1:3288902020

**Submission Date**

Des 2, 2023, 9:20 AM GMT+4:30

**Download Date**

Des 2, 2023, 9:23 AM GMT+4:30

**File Name**

Yulia.pdf

**File Size**

347.2 KB

17 Pages

6,960 Words

39,335 Characters

# 11% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

## Top Sources

- 3%  Internet sources
  - 5%  Publications
  - 3%  Submitted works (Student Papers)
-

## Top Sources

- 3% Internet sources
- 5% Publications
- 3% Submitted works (Student Papers)

## Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Internet	ejournals.vdu.lt	1%
2	Internet	journals.equinoxpub.com	<1%
3	Student papers	American College of Education	<1%
4	Student papers	Philippine Normal University	<1%
5	Internet	tused.org	<1%
6	Publication	Nonhlanhla Fortunate Nduku. "Exploring Teaching Perspectives Embraced by Tea..."	<1%
7	Student papers	Western Governors University	<1%
8	Publication	Renee Monica Henry. "Engaging Participation and Promoting Active Learning thr..."	<1%
9	Publication	Mindi Wang, Ling Jiang, Heng Luo. "Dyads or quads? Impact of group size and lea..."	<1%
10	Publication	David C. Haak, Scott Salom, Jacob N. Barney, Todd Schenk et al. "Transformative I..."	<1%
11	Publication	Michael R. Abraham, John W. Renner. "The sequence of learning cycle activities in..."	<1%

## **High-Performance Learning Cycle-Inquiry: Effects on Pre-Service Elementary Teachers' Science Process Skills and Content Knowledge**

**Yulia Eka Yanti<sup>1\*</sup>, Herawati Susilo<sup>2</sup>, Utami Sri Hastuti<sup>3</sup>**

<sup>1,2,3</sup>Department of Biology Education, Universitas Negeri Malang

<sup>1</sup>Department of Elementary School Teacher Education, Universitas Islam Raden Rahmat Malang

Corresponding author: yuliaekay@gmail.com

**ABSTRACT:** The present study explored the effects of Learning Cycle and Inquiry (LCI) on pre-service elementary teachers' science process skills and concept knowledge. During the one-semester period, four groups of students participated in this study. The experimental group (23 students) was taught using the LCI model. The positive control group 1 (23 students) learned using the inquiry, the positive control group 2 (18 students) learned using the learning cycle-5E model, and the negative control group (18 students) was involved in conventional learning processes. The pretest and post-test used in this study had undergone expert validation. The study results revealed statistically significant differences in the research participants' content knowledge and science process skills. The combination of Learning Cycle and Inquiry (LCI) can simultaneously promote students' science process skills and academic performance.

**Keywords:** science process skills; inquiry-based learning; content knowledge; learning cycle.

### **INTRODUCTION**

Recent global curriculum has focused on developing science-literate students (Akben 2015; Baptista and Molina-Andrade 2021). Science-literate students can understand scientific facts and apply science process skills (SPS) to solve science-related problems (OECD 2017). In different countries, science process skills (SPS) are an integral part of the school curriculum (Shahali et al. 2017; Wu and Wu 2011). Therefore, students must develop SPS to fully learn and understand science (Hofstein and Lunetta 2004). In short, modern education should aim to help students master concepts and apply SPS in everyday life. A balanced relationship between SPS and content knowledge (CK) is necessary to create a meaningful learning process (Tan et al. 2022).

Science process skills (SPS) are important because they play a major role in building students' competence and enthusiasm for science and various natural phenomena that occur in daily life (Erkol and Ugulu 2014; Duran et al. 2011). SPS help students develop higher thinking skills (HOTS), including critical thinking, decision making, and problem solving skills (Koray et al. 2007). SPS enable students at universities to find and develop facts and concepts themselves. Increased SPS ultimately leads to increased content knowledge (Coil et al. 2010).

However, some previous studies have shown that students have poor science process skills (Artayasa et al. 2017; Irwanto, Rohaeti, and

1 Prodjosantoso 2018; Fadilla et al. 2019; Andriyani, Shimizu, and Widiyatmoko 2019). Few students can learn methods of scientific thinking because most classroom instructions are not based on discovery (Gultepe and Kilic 2015). Traditional teaching methods are no longer sufficient to support the development of students' content knowledge and science process skills (Akben 2015). Conventional classrooms emphasize non-student-centered activities that fail to encourage students to understand topics and concepts (Idris, Talib, and Razali 2022). Most classroom learning activities only focus on helping students achieve high test scores without encouraging students to actively participate in class (Awelani and Fraser 2004). Thus, one factor that plays a significant role in underachieving is the quality of instruction (Luera, Moyer, and Everett 2005). To find a solution to this challenge, educational researchers conducted various studies. One is applying inquiry and learning cycle (LC) to enhance college students' science process skills and content knowledge.

The inquiry-based learning model has been implemented in the classroom to improve the science process skills of prospective teachers (Artayasa et al. 2017; Irwanto, Rohaeti, and Prodjosantoso 2018; Imaduddin and Hidayah 2019). The inquiry-based learning model offers higher education students the opportunity to obtain facts and explanations about natural phenomena, which can help them develop science process skills (Borrull and Valls 2021). Inquiry involves students' curiosity in developing experimental questions that can enhance their reasoning skills (Gultepe 2016). In addition, Irwanto et al. (2019) state that inquiry-based learning emphasizes critical thinking and science process skills rather than simply mastering scientific concepts.

On the other hand, the learning cycle (LC) focuses more on promoting content knowledge (Nopparatjamjomras and Nopparatjamjomras 2020; Koyunlu Ünlü and Dökme 2022). LC is designed to help teachers move from traditional to student-centered classrooms (Marfilinda, Zaturrahmi, and Indrawati 2019). LC helps students understand science concepts, encourages scientific reasoning, and engages students in the learning activities (Marek 2008). Ergin, Kanli, and Ünsal (2008) state that the LC-5E model allows students to learn new concepts, understand concepts that are already known in depth, and actively seek information for understanding.

This research discusses the performance of the combined Learning Cycle and Inquiry later known as the Learning Cycle-Inquiry (LCI). Several references describe the similarity of the inquiry phases and cycles of LC. LC is one of the most suitable models to combine with inquiry (Eroğlu and Bektaş 2022). LC was developed based on a scientific inquiry approach (Koyunlu Ünlü and Dökme 2022). Guided inquiry activities provide opportunities for students to address alternative conceptions (Garcia I Grau et al. 2021). The difference between the two is that the initial phase of LC suggests starting with an inductive approach, whereas the initial phase of inquiry suggests a deductive approach. However, induction and deduction can coexist and complement each other in the inquiry process (Pedaste et al. 2015). This study assessed college students' science process skills before and after the implementation of LCI-based learning. It also explored the effectiveness of the LCI learning model in increasing the students' content

knowledge. It is hoped that the results of this study can guide faculty and university curriculum designers to combine inquiry learning and learning cycle to teach science to prospective elementary school teachers.

## **METHODS**

### **Research Questions**

The present study was conducted to explore the effects of Learning Cycle and Inquiry (LCI) on college students' science process skills and content knowledge. Specifically, this study attempted to answer the following questions: 1. Are there any statistically significant differences in science process skills between LCI students and non-LCI students? 1. Are there any statistically significant differences in content knowledge between LCI and non-LCI students?

### **Context of the study**

The Department of Elementary School Teacher Education (ESTE) is part of the Indonesian national education system responsible for preparing and developing quality teacher resources. Elementary school is a fundamental level of education. It lies the foundation for a higher level of formal schooling. Therefore, the ESTE study program must produce teachers with extensive content knowledge, strong investigative skills, a strong learner spirit, and an adequate ability to apply learning methods or practices to improve learning quality.

The ESTE department applies a spiral development approach to material development to ensure systematic learning. One of the materials considered relevant and presented in the form of courses is the basic concepts of natural science, which is the context we wanted to explore. Since inquiry-based learning and learning cycle (LC) were implemented in science courses for science teachers (physics, chemistry, and biology), we were interested in combining learning cycle and inquiry and examining its effectiveness in basic science courses.

### **Design of the Study**

The present study employed a pretest-post-test nonequivalent control group design (Creswell 2014). Learning Cycle-Inquiry (LCI) was applied to improve college students' science process skills and content knowledge in a science basic course. The course lasted 16 weeks. Four freshman groups studying science were used as participants. All groups received the same lesson topics, namely the relationship between living things and the environment, the reproduction of living things, the organ system of the human body, and the importance of a healthy lifestyle. However, the topics were delivered using different instructions. In the experimental group, instruction was based on the LCI model. There were two positive control groups and one negative control group. To learn the topics, the positive control group 1 used the Inquiry learning phases, the positive control group 2 used the learning cycle (LC) 5E learning phases. In contrast, the negative control group used the conventional methods of learning.

## Participants

Four (4) groups of freshmen from a university in East Java, Indonesia participated in this study. The total number of the students was 82 students. They were enrolled in a basic science course. The four groups of participants consisted of the LCI group (23 students), the Inquiry group (23 students), the Learning Cycle-5E group (18 students), and the Conventional group (18 students). The four classes had a homogeneous variance and normal data distribution, confirmed by the Levene's Test for Equality of Variances and the One-sample Kolmogorov-smirnov test ( $p$ -value $>0.05$ ). All students agreed to be involved in this research from start to finish. Thus, their involvement was voluntary and without coercion.

## Instrumentation

### **Test for science process skills (SPS)**

The participants' science process skills were assessed using five essay questions that refer to five indicators: formulating hypotheses, identifying variables, designing experiments/investigations/observations, interpreting data, and drawing a conclusion (making an inference). A lecturer with science education expertise evaluated the face validity and content validity of the test. The test items were revised based on the expert recommendations. The revised items were then used in a field tryout. The field tryout was conducted on sophomore students to establish the validity and reliability of the test. Test validity was tested using Pearson Correlation. The results showed that only item number 5 had an insignificant  $p$ -value.

Meanwhile, the reliability test results revealed a Cronbach's alpha value of 0.80, indicating a high reliability level. The invalid test items were revised. All study groups used the revised test items in the pre-test and post-test. Below is an example of an empirically and theoretically valid science process skills test.

*Indicator: identifying variables*

*Question Number 2: Vita wants to do a simple study on "the effect of an organic fertilizer type on the growth of red bean sprouts". From the research title, determine:*

*a. the research variables*

*b. the formulation of the problems or the relationship between the research variables*

*c. the research hypothesis*

The test takers might score between 0-4 for Question No. 2. The criteria for each score are: 0 for "no variable was identified", 1 for "the identified variables were wrong", 2 for "can only identify one of them, the independent or dependent variable", 3 for "can identify all variables correctly, but cannot manipulate the variables", and 4 for "can identify and manipulate all variables correctly".

### **Test for content knowledge (CK)**

The participants' content knowledge was assessed using nine essay questions that refer to four subtopics taught in the basic science course.

The test belonged to a higher-order thinking test which measured the participants' abilities to analyze (C4), evaluate (C5), and create (C6). The difficulty of the test items was based on the revised Blooms taxonomy. This test was validated by a science lecturer and tried out to a group of sophomores. The face and content validity tests showed that five questions were invalid ( $p$ -value  $> 0.05$ ) and needed minor revisions. The reliability test showed high reliability (a Cronbach's alpha value of 0.85). The following contains an example of an empirically and theoretically valid content knowledge test.

*Indicator 1: the relationship between living things and the environment (C4-Analyzing)*

*Question Number 1: Humans hunt birds for their uniqueness and their usefulness as food. Birds have a vital role in the balance of a tree ecosystem.*

- a. Name the biotic and abiotic components in a tree ecosystem! Give one example of the relationship between biotic components influenced by abiotic components in the tree ecosystem!*
- b. Draw the tree ecosystem food web!*
- c. Explain the position of birds in the tree ecosystem organization level and if there is continuous hunting, what will happen to the balance of the tree ecosystem?*

### **Data collection procedure**

First, we sent a letter to the department head of the ESTE department at the target university. The head of the study program recommended that we meet the lecturer in charge of the basic science course. We then communicated informally by telephone to discuss informed consent with the lecturer. After obtaining consent, four classes were determined based on the results of the equivalence test on the students' GPA. We randomly selected one student group as the experimental class and the other three as control groups. Two weeks before conducting the treatment, participants were acclimatized to get used to the learning atmosphere of the LCI model, the exam, and the 5E learning cycle. The acclimation session was given to the students to prepare them to use the models, allowing the lessons to be better managed and the learning process to be more effective. In the first and sixteenth weeks of the course, all participants completed the same pre- and post-test on scientific process skills and content knowledge. The collected data was then statistically evaluated.

### **The Learning Cycle-Inquiry (LCI) Implementation**

Learning Cycle-Inquiry (LCI) is a combination of two learning models, namely Learning Cycle (LC) 5E developed by Bybee et al. (2006) and Inquiry proposed by Llewellyn (2012). The LCI learning process begins by creating a condition that prepares students to participate in learning. This stage involves students connecting past and present experiences and organizing their thoughts to achieve learning goals. Then, LCI encourages students to explore interesting subjects and seek problems from a phenomenon. LCI facilitates students to find ideas that increase understanding to solve a problem. Learning in the LCI classroom involves students learning to interpret the meaning of a phenomenon, problem, data, or other

information. The LCI model includes activities that can increase student motivation, strengthen their scientific process skills, and critical thinking through inquiry activities and reasoning. Finally, in the LCI classroom, students conduct elaboration and assessment of the implemented learning activities. Table 1 maps the LCI syntax in detail.

Syntax	Description	Learning Activities
Orienting students to the process of learning	<ul style="list-style-type: none"> <li>○ Creates a condition in which students are prepared to learn</li> <li>○ Introduces students to the objectives and stages of learning</li> <li>○ Motivates students through apperception activities</li> <li>○ Prepares students for group work</li> </ul>	Students are divided into groups of 2 or 3  Encourages students to think by asking “Have you ever grown sprouts? How did you do it?”
Exploring knowledge	<ul style="list-style-type: none"> <li>○ Provides students with the opportunity to engage in the learning process, by letting them explore an interesting object or situation</li> <li>○ Asks and stimulates students to identify and formulate the problem</li> </ul>	Students determine the problem that is going to be investigated, for example “Can the growth media affect the germination of long bean seeds?” then identify the dependent variable of the research, for example “the number of leaves” and the independent of the research, for example “growth media”
Formulating hypotheses	Asks students to think about the temporary solution to the problem	Students formulate a temporary assumption to solve the problem, for example “The growth media may affect the germination of the long bean seeds”
Explaining	<ul style="list-style-type: none"> <li>○ Students design an investigation</li> <li>○ Students do investigation activities to collect information to test the hypothesis (for example, via observation, experiment, practicum, reading, or discussion)</li> </ul>	Students establish the investigation schedule, tool and material, and procedure
Analyzing and interpreting data	Students determine the acceptable answer to the problem based on the collected data or information. Students develop skills in explaining meaning of a problem, an issue, data, or other information.	Students analyze data and present it in the form of tables or images of “the length of the long bean sprout stem (in cm)” and “the number of leaves”
Drawing conclusion	a Students conclude and describes the investigation findings based on the analysis results and data interpretation.	Students conclude by stating that “the growth media affect the germination of long bean seeds”
Elaborating	Students do activities that strengthen and elaborate the concepts received from learning. The activities relate to the application of concepts in everyday	Students elaborate the concept of growth by assuming that external factors, such as nutrients

	life.	in the soil and fertilization can influence the growth of long bean seeds.
Evaluating	Students evaluate the learning process and reflect on their progress in acquiring knowledge during the learning process.	Students reflect on problems and insights obtained during the learning process.

**Data analysis**

Data analysis was performed using descriptive and inferential statistics. Descriptive statistics was used to obtain the mean (M) of the pre- and post-test scores and the standard deviation (SD) of the scores. In addition, inferential statistics was used to analyze covariance (ANCOVA) with the pretest score as the covariate. ANCOVA was run to examine the difference in science process skills and content knowledge between the experimental and control groups. The LSD test was conducted because ANCOVA showed a p-value smaller than 0.05 (significant).

**RESULTS**

**Science process skills**

Based on the actual means of participants’ science process skills (Figure 1), the LCI group performed better than the other groups in the pretest, with a mean of 36.81 (SD= 2.53). Meanwhile, the Inquiry and LC groups obtained mean scores of 32.57 (SD= 2.61) and 32.38 (SD= 3.23), respectively. Conversely, the conventional group achieved slightly less than the Inquiry and LC groups, namely 31.08 (SD= 3.33). In the post-test, the LCI group achieved a mean score of 86.02 (SD= 2.84) and is therefore better than the other groups. There was no significant difference between the Inquiry, LC, and conventional groups regarding post-test score. The scores achieved by the groups were 79.46 (SD= 2.60), 76.13 (SD= 3.09), and 74.61 (SD= 3.30), respectively.

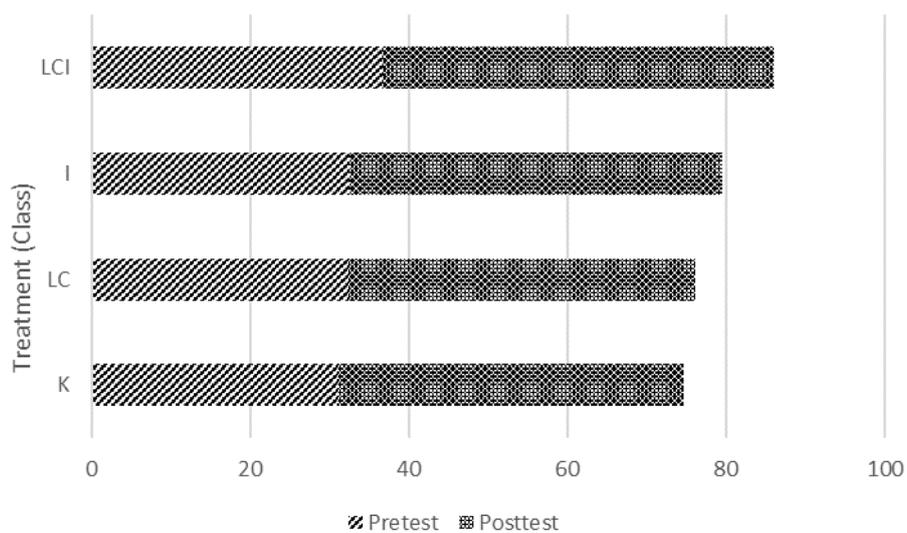


Figure 1. The actual mean of participants’ pretest dan post-test on science process skills

**Note.** LCI = Learning Cycle-Inquiry, I = Inquiry, LC = Learning Cycle, K = Conventional

The inferential statistics ANCOVA was run to confirm the difference in participants' performance in science process skills, using pretest scores as covariates. The ANCOVA results proved that the research treatment influenced the increase in participants' science process skills. Table 2 records the ANCOVA results showing that each research treatment affected participants' science process skills significantly differently. Therefore, an LSD test was conducted to examine which learning model could significantly affect participants' science process skills.

**Table 2.** The ANCOVA Results of Participants' Science Process Skills

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	2658.308	1	2658.308	277.300	.000
	Error	421.049	43.921	9.586		
Pretest	Hypothesis	85.929	1	85.929	11.247	.001
	Error	588.290	77	7.640		
Group	Hypothesis	721.295	3	240.432	31.470	.000
	Error	588.290	77	7.640		

The LSD test results indicated that the LCI model had the most significant effect on participants' science process skills, compared to the other learning models (i.e., Inquiry, Learning Cycle, and Conventional). Therefore, the LCI model increased participants' science process skills more effectively than the Inquiry, Learning Cycle, and Conventional models. Furthermore, the results also proved that the LC and Inquiry models enhanced participants' science process skills more significantly than the conventional model. As shown by the estimated marginal means (EM), participants studied with the LCI model performed better on science process skills (mean 84.78) than participants studied with the inquiry, the learning cycle, or the conventional models (mean 79.76, 76.49 and 75.45) (Figure 2). These findings indicate that the LCI model had the best potential to improve students' science process skills.

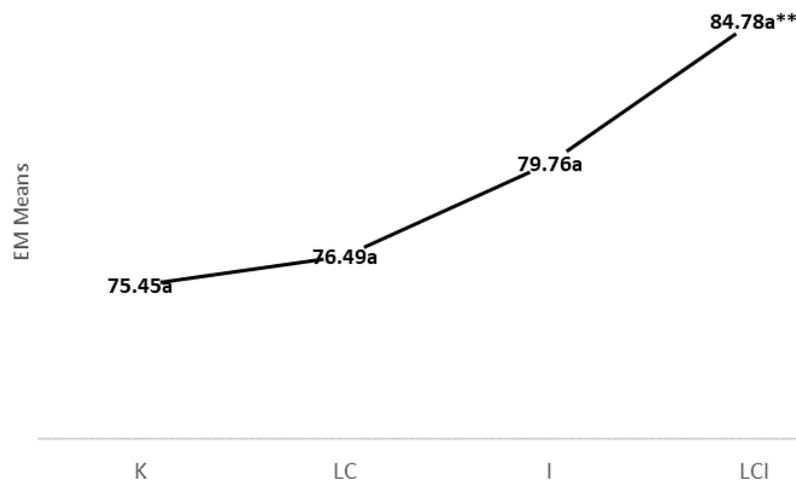


Figure 2. The estimated marginal means (EM) of participants' posttest on science process skills

**Note.** a= covariates appearing in this model are evaluated at pre-test = 33.39; 95% CI.

\*\* = significantly different from other groups (p <0.01)

LCI= Learning Cycle-Inquiry, I= Inquiry, LC= Leaning Cycle, K= Conventional

**Content Knowledge**

Figure 3 shows that the LCI group performed better than the other groups in the pretest with a mean score of 35.35 (SD= 2.87). Then the LC group achieved a mean score of 32.92 (SD= 3.08), followed by the Inquiry and conventional groups with mean scores of 30.62 (SD= 3.03) and 29.77 (SD= 3.22), respectively. In the post-test, the LCI group obtained a mean score of 86.02 (SD= 2.84) and is thus above the mean scores of the other groups. The LC group reported a mean score of 80.51 (SD= 3.13) for the posttest. Meanwhile, the Inquiry (mean=74.95; SD= 4.79) and conventional groups (mean= 71.80; SD= 5.58) had lower mean scores than those of the LCI and LC groups.

The inferential statistics ANCOVA was run to confirm the difference in participants' performance in science process skills, using pretest scores as covariates. The ANCOVA results proved that the research treatment influenced the increase in participants' science process skills. Table 2 records the ANCOVA results showing that each research treatment affected participants' science process skills significantly differently. Therefore, an LSD test was conducted to examine which learning model could significantly affect participants' science process skills.

An analysis of covariance (ANCOVA) was performed to confirm the difference in participants' performance on content knowledge. The ANCOVA results in Table 4 show a score of 0.000 for the significance of the model, proving that the implementation of different learning models significantly affected participants' content knowledge. In other words, four learning models had different potentials for influencing students' knowledge growth. Therefore, an LSD test was carried out.

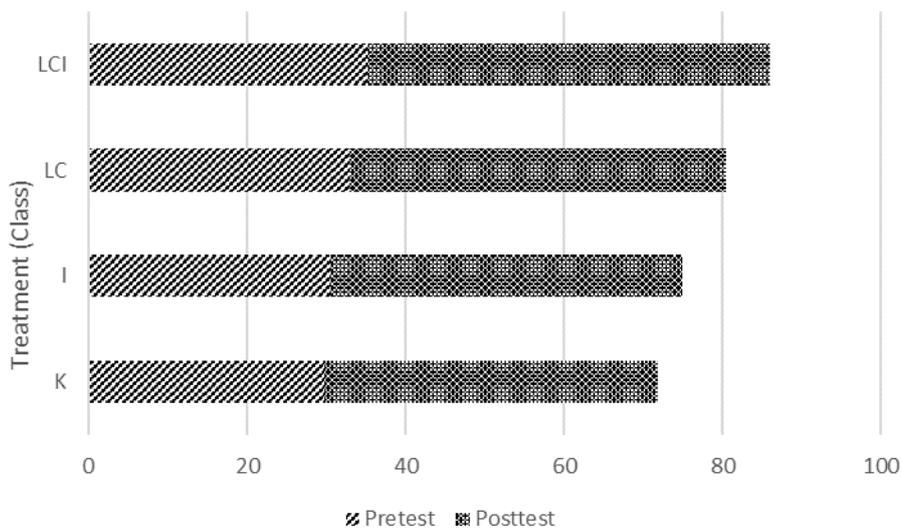


Figure 3. The estimated marginal means (EM) of participants' posttest on content knowledge

**Note.** LCI= Learning Cycle-Inquiry, I= Inquiry, LC= Leaning Cycle, K= Conventional

**Table 4.** The ANCOVA Results of Participants' Content Knowledge

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	3414.290	1	3414.290	135.120	.000
	Error	1751.225	69.305	25.269		
Pretest	Hypothesis	38.157	1	38.157	1.684	.198
	Error	1744.415	77	22.655		
Group	Hypothesis	876.689	3	292.230	12.899	.000
	Error	1744.415	77	22.655		

As shown by the estimated marginal means (EM), participants studied with the LCI and LC models had similar performance on science process skills (mean 82.64 and 80.36, respectively). However, the content knowledge of students from the Inquiry (75.33) and conventional (72.37) groups was lower than the participants in the LCI and LC groups (Figure 4). These findings indicate that the LCI model had the best potential to improve students' science process skills.

The LSD test results indicated that the LCI model differed significantly from the Inquiry and Conventional models yet had similar effects with the LC model in enhancing participants' content knowledge. Therefore, it was concluded that the LCI and LC models were more effective than the inquiry and conventional models in improving students' content knowledge. This finding suggests that the LCI and LC models had the same potential to improve college students' content knowledge.

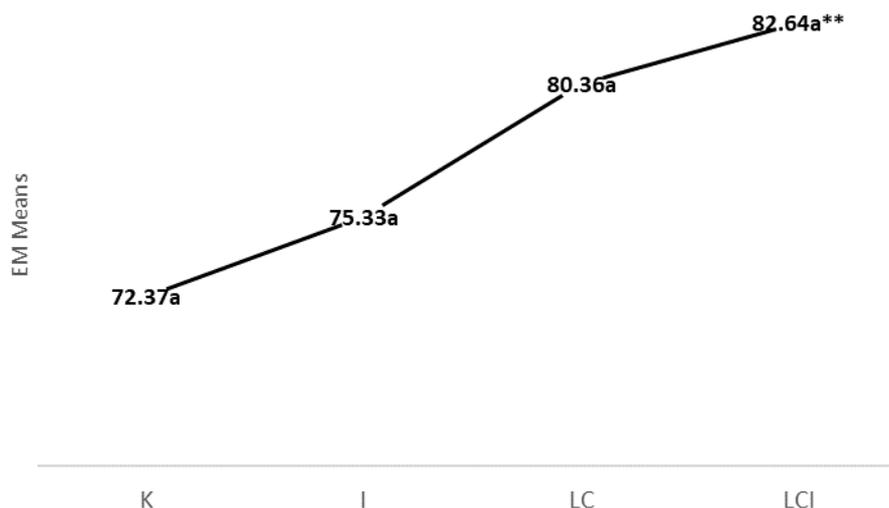


Figure 4. The estimated marginal means (EM) of participants' posttest on content knowledge

**Note.** a= covariates appearing in this model are evaluated at pre-test =32.37; 95% CI.

\*\* = significantly different from other groups (p <0.01)

LCI= Learning Cycle-Inquiry, I= Inquiry, LC= Learning Cycle, K= Conventional

**DISCUSSION**

The present study aimed to investigate the effect of the LCI learning model on college students' science process skills (SPS) and content knowledge (CK). College students involved in this study came from the department of elementary school teacher education (ESTE). When this study

was conducted, the students were enrolled in a basic science course at the target university. College students must develop SPS and CK to achieve scientific literacy (Sjöström and Eilks 2018). Learning Cycle-Inquiry (LCI), as a combination of inquiry and LC, is expected to be the best alternative learning model for improving student performance in science compared to implementing the two models separately or traditional learning.

The main finding of this study was that students exposed to LCI experienced a more significant increase in SPS and CK than students exposed to inquiry, LC, and conventional models. This result is supported by the high EM score obtained by LCI. In other words, the LCI learning model has proven high effectiveness in improving students' SPS and CK. There are several reasons why LCI has the highest effectiveness. *First*, experiential activities in the LCI classroom emphasize student independence. In the LCI class, students are trained to design experiments, collect data, and draw conclusions without much help from the instructor (Teig, Scherer, and Nilsen 2018). This series of activities requires students to interact with each other to more easily achieve common learning goals (Mende, Proske, and Narciss 2021). Group experiments conducted by LCI students allow discovery (Rannastu et al. 2019) and knowledge construction (Jerrim, Oliver, and Sims 2019).

*Second*, before elaborating, students make generalizations or valid conclusions based on the experimental results. This stage allows students to draw relevant contextual information and modify their understanding of the phenomena they have studied (Teo and Goh 2019). Further, inference skills require higher cognitive processes than just remembering information. These skills are relevant to CK and inquiry activities, and are an integral component of SPS (National Research Council 2011).

*Third*, in the elaboration phase, students are not only asked to carry out ongoing investigative activities, but are also invited to conduct small experiments accompanied by various questions to strengthen understanding. Asking questions is a constructivist learning method (Crogman and Trebeau Crogman 2016). Questions asked in LCI classes can encourage students to think critically (Thompson 2018) and help them strengthen understanding (Aguilera and Perales-Palacios 2020; Salmon and Barrera 2021). Thus, students can strengthen concepts during the elaboration phase by extending and applying facts to real situations and new contexts (Llewellyn 2012).

Another advantage of LCI learning is that students can measure their abilities and knowledge at the evaluation stage. This activity can help students improve their work to be ready for further learning (Tai et al. 2018). LCI students tend to be more prepared to learn material because they have read more resources needed to supplement their knowledge. In addition, evaluation activities are an important aspect of problem-solving and investigation activities (Arends 2011). In conclusion, LCI can familiarize students in using SPS to solve problems (Tai et al. 2018).

LCI does not only emphasize cognitive processes, but also involves students in mental activities (Jack 2017). Complex learning stages in LCI can help students find complete knowledge to minimize errors in understanding the material being studied. Students who experience each

process of acquiring knowledge themselves will find it easier to remember the concepts learned (Hanuscin and Lee 2008).

The SPS measurement results indicated that students exposed to the inquiry model had EM scores almost the same as LCI students. However, from the CK aspect, students exposed to LC have almost the same content knowledge scores as LCI. This result is because inquiry-based learning emphasizes designing and conducting experiments. The syntax of the inquiry model can foster students' SPS (Artayasa et al. 2017; Irwanto, Rohaeti, and Prodjosantoso 2018; Imaduddin and Hidayah 2019).. Meanwhile, students with LC are more focused on developing CK (Nopparatjamjomras and Nopparatjamjomras 2020; Koyunlu Ünlü and Dökme 2022) through activities to solve questions that are described in worksheets.

Meanwhile, the conventional model is considered the least effective for increasing students' SPS and CK because this learning model does not require students to explore their skills in depth. Prayitno et al. (2017) explain that conventional learning methods often force learners to memorize the knowledge they receive. Therefore, during conventional teaching, students do not experience knowledge discovery through investigations of the phenomena around them. In addition, their SPS is also difficult to develop.

Although the results of this study provide valuable information through establishing three unbiased control groups, some limitations must be recognized. *First*, this study focused on measuring participants' initial and final academic performance using a test instrument that could not examine changes in student abilities from time to time from multiple perspectives. Future research will need to perform a variety of measurements with more than one type of instrument, for example by using a self-report questionnaire. This instrument can better portray the profile of students' and teachers' scientific process skills and content knowledge. *Second*, future research must also consider the students' background, including the type of institution they study at. Thus, a comparative analysis of SPS and CK can be related to school type, gender, and geographic location. Such an analysis will provide more comprehensive insights to help researchers and policy makers see the implications of creating a new learning model by combining some learning models such as LCI. *Third*, the impact of LCI may not be limited to SPS and CK in basic science but may extend to other skills and disciplines. In the future, research may consider other variables such as problem solving, critical thinking, and learning motivation to expand the effect of LCI on student skills.

## CONCLUSION AND IMPLICATIONS

There was a significant difference in science process skills (SPS) between students in the LCI class and those in the I, LC, and K groups. Significant differences in content knowledge (CK) were also found between students in LCI and those in the I and K groups. This finding suggests that LCI offers more opportunities for students to practice and improve their SPS. In addition, teachers can use LCI as an effective teaching-learning intervention to promote CK. The LCI learning model can positively and

effectively affect students' SPS and CK on basic science concepts. Based on these findings, faculty should not only focus on CK but also strive to develop SPS.

Faculty should modify the LC worksheet to include investigation steps. LCI creates a student-centered classroom environment, improves collaboration, and promote student engagement. However, before implementing LCI in the classroom, faculty must hold a session to present this model at the beginning of learning to familiarize students with the steps and learning activities in LCI. Also, for the sake of time efficiency, lecturers must clearly explain the learning steps at the beginning of the lesson. Some students have little initial knowledge and tend to be slow to explore their knowledge and complete the worksheets given. To overcome this, lecturers must instruct students to maximize group collaboration to create an atmosphere of active discussion and positive interaction.

### ACKNOWLEDGEMENT

Our heartfelt gratitude goes to Universitas Negeri Malang dan Universitas Islam Raden Rahmat Malang who have supported and facilitated this research.

### REFERENCES

- Aguilera, David, and Francisco Javier Perales-Palacios. 2020. "Learning Biology and Geology through a Participative Teaching Approach: The Effect on Student Attitudes towards Science and Academic Performance." *Journal of Biological Education* 54 (3): 245–61. <https://doi.org/10.1080/00219266.2019.1569084>.
- Akben, Nimet. 2015. "Improving Science Process Skills in Science and Technology Course Activities Using the Inquiry Method." *TED EĞİTİM VE BİLİM* 40 (May). <https://doi.org/10.15390/EB.2015.4266>.
- Andriyani, R., K. Shimizu, and A. Widiyatmoko. 2019. "The Effectiveness of Project-Based Learning on Students' Science Process Skills: A Literature Review." *Journal of Physics: Conference Series* 1321 (3): 032121. <https://doi.org/10.1088/1742-6596/1321/3/032121>.
- Arends, Richard. 2011. *Learning to Teach, 9th Edition*. 9th edition. Dubuque, Iowa: McGraw-Hill Education.
- Artayasa, Putu, Herawati Susilo, Umie Lestari, and Sri Endah Indriwati. 2017. "The Effectiveness of the Three Levels of Inquiry in Improving Teacher Training Students' Science Process Skills." *Journal of Baltic Science Education* 16 (6): Continuous. <https://doi.org/10.33225/jbse/17.16.908>.
- Awelani, Rambuda, and William Fraser. 2004. "Perceptions of Teachers of the Application of Science Process Skills in the Teaching of Geography in Secondary Schools in the Free State Province." *South African Journal of Education Copyright EASA Vol 24* (January): 10–17.
- Baptista, Geilsa Costa Santos, and Adela Molina-Andrade. 2021. "Science Teachers' Conceptions About the Importance of Teaching and How to Teach Western Science to Students from Traditional Communities." *Human Arenas*, October. <https://doi.org/10.1007/s42087-021-00257-4>.

- Borrull, Anna, and Cristina Valls. 2021. "Inquiry Laboratory Activity: Investigating the Effects of Mobile Phone on Yeast Viability." *Journal of Turkish Science Education* 18 (2): 176–91.
- Bybee, Rodger, Joseph Taylor, April Gardner, Pamela Scotter, Janet Carlson, Anne Westbrook, and Nancy Landes. 2006. "The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications." *BSCS*, January.
- 10 Coil, David, Mary Pat Wenderoth, Matthew Cunningham, and Clarissa Dirks. 2010. "Teaching the Process of Science: Faculty Perceptions and an Effective Methodology." *CBE Life Sciences Education* 9 (4): 524–35. <https://doi.org/10.1187/cbe.10-01-0005>.
- Creswell, John W. 2014. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. 4th edition. Thousand Oaks: SAGE Publications, Inc.
- Crogman, Horace, and Maryam Trebeau Crogman. 2016. "Generated Questions Learning Model (GQLM): Beyond Learning Styles." Edited by John Lee. *Cogent Education* 3 (1): 1202460. <https://doi.org/10.1080/2331186X.2016.1202460>.
- Duran, Meltem, Hakan Işık, Gülcan Mihaladiz, and Oğuz Özdemir. 2011. "The Relationship between the Pre-Service Science Teachers' Scientific Process Skills and Learning Styles." <http://acikerisim.deu.edu.tr:8080/xmlui/handle/20.500.12397/5206>.
- Ergin, İsmet, Uygur Kanli, and Yasin Ünsal. 2008. "An Example for the Effect of 5E Model on the Academic Success and Attitude Levels of Students': 'Inclined Projectile Motion.'" *Journal of Turkish Science Education* 5 (3): 47–59.
- 7 Erkol, Sevilay, and Ilker Ugulu. 2014. "Examining Biology Teachers Candidates' Scientific Process Skill Levels and Comparing These Levels in Terms of Various Variables." *Procedia - Social and Behavioral Sciences*, 5th World Conference on Educational Sciences, 116 (February): 4742–47. <https://doi.org/10.1016/j.sbspro.2014.01.1019>.
- Eroğlu, Seyide, and Oktay Bektaş. 2022. "The Effect of 5E-Based STEM Education on Academic Achievement, Scientific Creativity, and Views on the Nature of Science." *Learning and Individual Differences* 98 (August): 102181. <https://doi.org/10.1016/j.lindif.2022.102181>.
- Fadilla, Niki, Luthfiyah Nurlaela, Maspiyah, and Mohamad Nur. 2019. "Analysis of Student Science Process Skills in Faculty of Engineering State University of Surabaya." In , 214–22. Atlantis Press. <https://doi.org/10.2991/assehr.k.191217.036>.
- Garcia I Grau, Francesc, Cristina Valls, Núria Piqué, and Héctor Ruiz-Martín. 2021. "The Long-Term Effects of Introducing the 5E Model of Instruction on Students' Conceptual Learning." *International Journal of Science Education* 43 (9): 1441–58. <https://doi.org/10.1080/09500693.2021.1918354>.
- Gultepe, Nejla. 2016. "High School Science Teachers' Views on Science Process Skills." *International Journal of Environmental and Science Education* 11 (5): 779–800.

- Gultepe, Nejla, and Ziya Kilic. 2015. "Effect of Scientific Argumentation on the Development of Scientific Process Skills in the Context of Teaching Chemistry." *International Journal of Environmental and Science Education*, January. <http://www.ijese.net/makale/151.html>.
- Hanuscin, Deborah L., and Michele H. Lee. 2008. "Using the Learning Cycle as a Model for Teaching the Learning Cycle to Preservice Elementary Teachers." *Journal of Elementary Science Education* 20 (2): 51–66. <https://doi.org/10.1007/bf03173670>.
- Hofstein, Avi, and Vincent N. Lunetta. 2004. "The Laboratory in Science Education: Foundations for the Twenty-First Century." *Science Education* 88 (1): 28–54. <https://doi.org/10.1002/sce.10106>.
- Idris, Nazihah, Othman Talib, and Fazilah Razali. 2022. "Strategies in Mastering Science Process Skills in Science Experiments: A Systematic Literature Review." *Jurnal Pendidikan IPA Indonesia* 11 (1): 155–70. <https://doi.org/10.15294/jpii.v11i1.32969>.
- 5 Imaduddin, Muhamad, and Fitria Fatichatul Hidayah. 2019. "Redesigning Laboratories for Pre-Service Chemistry Teachers: From Cookbook Experiments to Inquiry-Based Science, Environment, Technology, and Society Approach." *Journal of Turkish Science Education* 16 (4): 489–507.
- 8 Irwanto, Irwanto, Eli Rohaeti, and Anti Prodjosantoso. 2018. "Undergraduate Students' Science Process Skills in Terms of Some Variables: A Perspective from Indonesia." *Journal of Baltic Science Education* 17 (November): 751–64.
- Irwanto, Anip Dwi Saputro, Eli Rohaeti, and Anti Kolonial Prodjosantoso. 2019. "Using Inquiry-Based Laboratory Instruction to Improve Critical Thinking and Scientific Process Skills among Preservice Elementary Teachers." *Eurasian Journal of Educational Research*. <https://eric.ed.gov/?id=EJ1211675>.
- Jack, Gladys Uzezi. 2017. "The Effect of Learning Cycle Constructivist-Based Approach on Students' Academic Achievement and Attitude towards Chemistry in Secondary Schools in North-Eastern Part of Nigeria." *Educational Research and Reviews* 12 (7): 456–66. <https://doi.org/10.5897/ERR2016.3095>.
- Jerrim, John, Mary Oliver, and Sam Sims. 2019. "The Relationship between Inquiry-Based Teaching and Students' Achievement. New Evidence from a Longitudinal PISA Study in England." *Learning and Instruction* 61 (June): 35–44. <https://doi.org/10.1016/j.learninstruc.2018.12.004>.
- Koray, Ozlem, Mustafa Koksak, Muhammet Özdemir, and Arzu Presley. 2007. "The Effect of Creative and Critical Thinking Based Laboratory Applications on Academic Achievement and Science Process Skills." *Elementary Education Online* 6 (January): 377–89.
- Koyunlu Ünlü, Zeynep, and İlbilge Dökme. 2022. "A Systematic Review of 5E Model in Science Education: Proposing a Skill-Based STEM Instructional Model within the 21-St Century Skills." *International Journal of Science Education* 44 (13): 2110–30. <https://doi.org/10.1080/09500693.2022.2114031>.

- Llewellyn, Douglas J. 2012. *Teaching High School Science Through Inquiry and Argumentation*. Second edition. Thousand Oaks, California: Corwin.
- Luera, Gail R., Richard H. Moyer, and Susan A. Everett. 2005. "What Type and Level of Science Content Knowledge of Elementary Education Students Affect Their Ability to Construct an Inquiry-Based Science Lesson?" *Journal of Elementary Science Education* 17 (1): 12–25. <https://doi.org/10.1007/BF03174670>.
- Marek, Edmund. 2008. "Why the Learning Cycle?" *Journal of Elementary Science Education* 20 (April): 63–69. <https://doi.org/10.1007/BF03174709>.
- Marfilinda, Riri, Zaturrahmi, and Ena Suma Indrawati. 2019. "Development and Application of Learning Cycle Model on Science Teaching and Learning: A Literature Review." *Journal of Physics: Conference Series* 1317 (1): 012207. <https://doi.org/10.1088/1742-6596/1317/1/012207>.
- Mende, Stephan, Antje Proske, and Susanne Narciss. 2021. "Individual Preparation for Collaborative Learning: Systematic Review and Synthesis." *Educational Psychologist* 56 (1): 29–53. <https://doi.org/10.1080/00461520.2020.1828086>.
- National Research Council. 2011. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. <https://doi.org/10.17226/13165>.
- Nopparatjamjomras, Thasaneeya Ratanaroutai, and Suchai Nopparatjamjomras. 2020. "Teaching Integration of 5E Instructional Model and Flower Components." In *Science Education in the 21st Century: Re-Searching Issues That Matter from Different Lenses*, edited by Tang Wee Teo, Aik-Ling Tan, and Yann Shiou Ong, 253–67. Singapore: Springer. [https://doi.org/10.1007/978-981-15-5155-0\\_17](https://doi.org/10.1007/978-981-15-5155-0_17).
- OECD. 2017. *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematics, Financial Literacy and Collaborative Problem Solving*. PISA. OECD. <https://doi.org/10.1787/9789264281820-en>.
- Pedaste, Margus, Mario Mäeots, Leo A. Siiman, Ton de Jong, Siswa A. N. van Riesen, Ellen T. Kamp, Constantinos C. Manoli, Zacharias C. Zacharia, and Eleftheria Tsourlidaki. 2015. "Phases of Inquiry-Based Learning: Definitions and the Inquiry Cycle." *Educational Research Review* 14 (February): 47–61. <https://doi.org/10.1016/j.edurev.2015.02.003>.
- Prayitno, Baskoro, Duran Corebima Aloysius, Herawati Susilo, Siti Zubaidah, and Murni Ramli. 2017. "Closing the Science Process Skills Gap between Students with High and Low Level Academic Achievement." *Journal of Baltic Science Education* 16 (April): 266–77. <https://doi.org/10.33225/jbse/17.16.266>.
- Rannastu, Meeli, Leo Aleksander Siiman, Mario Mäeots, Margus Pedaste, and Äli Leijen. 2019. "Does Group Size Affect Students' Inquiry and Collaboration in Using Computer-Based Asymmetric Collaborative Simulations?" In *Advances in Web-Based Learning – ICWL 2019*, edited by Michael A. Herzog, Zuzana Kubincová, Peng Han, and Marco

- Temperini, 143–54. Catatan Kuliah Seri Buku Ilmu Komputer. Cham: Springer International Publishing. [https://doi.org/10.1007/978-3-030-35758-0\\_14](https://doi.org/10.1007/978-3-030-35758-0_14).
- Salmon, Angela K., and Maria Ximena Barrera. 2021. “Intentional Questioning to Promote Thinking and Learning.” *Thinking Skills and Creativity* 40 (June): 100822. <https://doi.org/10.1016/j.tsc.2021.100822>.
- Shahali, Edy H. M., Lilia Halim, David F. Treagust, Mihye Won, and A. L. Chandrasegaran. 2017. “Primary School Teachers’ Understanding of Science Process Skills in Relation to Their Teaching Qualifications and Teaching Experience.” *Research in Science Education* 47 (2): 257–81. <https://doi.org/10.1007/s11165-015-9500-z>.
- Sjöström, Jesper, and Ingo Eilks. 2018. “Reconsidering Different Visions of Scientific Literacy and Science Education Based on the Concept of Bildung.” In *Cognition, Metacognition, and Culture in STEM Education: Learning, Teaching and Assessment*, edited by Yehudit Judy Dori, Zemira R. Mevarech, and Dale R. Baker, 65–88. Innovations in Science Education and Technology. Cham: Springer International Publishing. [https://doi.org/10.1007/978-3-319-66659-4\\_4](https://doi.org/10.1007/978-3-319-66659-4_4).
- 2 Tai, Joanna, Rola Ajjawi, David Boud, Phillip Dawson, and Ernesto Panadero. 2018. “Developing Evaluative Judgement: Enabling Students to Make Decisions about the Quality of Work.” *Higher Education* 76 (3): 467–81. <https://doi.org/10.1007/s10734-017-0220-3>.
- Tan, Aik-Ling, Yann Shiou Ong, Yong Sim Ng, and Jared Hong Jie Tan. 2022. “STEM Problem Solving: Inquiry, Concepts, and Reasoning.” *Science & Education*, January. <https://doi.org/10.1007/s11191-021-00310-2>.
- 4 Teig, Nani, Ronny Scherer, and Trude Nilsen. 2018. “More Isn’t Always Better: The Curvilinear Relationship between Inquiry-Based Teaching and Student Achievement in Science.” *Learning and Instruction* 56 (August): 20–29. <https://doi.org/10.1016/j.learninstruc.2018.02.006>.
- Teo, Tang Wee, and Wee Pin Jonathan Goh. 2019. “Assessing Lower Track Students’ Learning in Science Inference Skills in Singapore.” *Asia-Pacific Science Education* 5 (1): 5. <https://doi.org/10.1186/s41029-019-0033-z>.
- Thompson, Carol C. 2018. “Advancing Critical Thinking Through Learning Issues in Problem-Based Learning.” *Medical Science Educator* 29 (1): 149–56. <https://doi.org/10.1007/s40670-018-00649-2>.
- 3 Wu, Hsin-Kai, and Chia-Lien Wu. 2011. “Exploring the Development of Fifth Graders’ Practical Epistemologies and Explanation Skills in Inquiry-Based Learning Classrooms.” *Research in Science Education* 41 (3): 319–40. <https://doi.org/10.1007/s11165-010-9167-4>.