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The Effectiveness of STLC (Science Technology Learning Cycle) To Empowering Critical Thinking Skills

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Critical thinking skills (CTS) is an important goal in higher education. The purpose of this study is to determine the practicality and effectiveness of the Science Technoloy Learning Cycle (STLC) model to empower CTS in the course of science concept development (SCD). This study is a pretest-posttest control group design by 4 theme in SCD course. The number of samples in this study was seventy-three students who were divided into experimental and control classes. By sampling technique, sample were from a population of students who took the SCD course in the department of elementary teacher education at PGRI University of Semarang in the academic year of 2018/2019. The results showed that the STLC model was practical or workable as indicated by the lecturer and students' activities classified into both good and very good categories. The STLC model was significantly effective in empowering CTS. For further research, the STLC as an alternative learning model that to empower critical thinking skills at various education level, especially in preparing teacher candidates.

Keywords: critical thinking skills, effectiveness, pre-service teacher, elementary school, science concept development, STLC learning model

INTRODUCTION

Critical thinking becomes the ultimate goal of learning at the college level (Heft & Scharff, 2017; Wilcox, et al, 2017; Schendel & Tolmie, 2017; Tiruneh, et al, 2018). Colleges become the backbone of a complete change in society because success at the college level is a bright spot for change to the lower levels. Therefore, several countries such as Australia, Mexico, Singapore, and Namibia place the function of higher

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education to produce graduates who can think critically in their curriculum documents (Vista, et al, 2018). According to Vista et al (2018), of 153 countries studied, there is seventy-six percent of the countries which include critical thinking skills (referred to as CTS) in higher education curriculum documents.

According to Ahmatika (2017), two factors are causing CTS not to develop in learning, namely the target of the curriculum which is merely material-based and learning activities delivered by the teacher that are still dominated by a lecturing method. . The teacher relies on a lecturing method to convey the concept because it is more economical even though, in general, it makes students more passive and discourages them to think critically (Mustofa & Yuwana, 2016; Baguma, et al, 2019). Conversely, active learning can improve CTS (Kusumoto, 2018). Therefore, learning processes in higher education must have a unique way to prepare each individual to be an agent of change (Kadir, 2017; Caudle & Paulsen, 2017), solve problems independently, be sensitive to environmental obstacles, think critically, work together in teams, communicate effectively, and dare to take risks (Rusmansyah, et al, 2019). Especially for pre-service teacher elementary school, CTS becomes a provision for guiding them to be well prepared and more adaptive in accepting rapid and global changes.

In Indonesia, CTS as the targets for higher education outcomes are set out in the INQF (Indonesian National Qualifications Framework) in Presidential Regulation No. 8 of 2012 and implemented through Ministry of Education and Culture Regulation No. 73 of 2013. Based on the Presidential Regulation, there are nine levels of qualifications starting from Diploma 1 to Doctorate. Undergraduate students are at level 6 with qualifications that read: "Being able to apply their field of expertise and utilize science, technology, and/or art in their field in problem-solving and being able to adapt to the situation at hand." To meet these qualifications, students who are prospective teachers need to be equipped with attitude, knowledge, general skills, and special skills as their learning achievements. Elementary school teachers must be facilitated to have CTS in all fields including science. CTS should be embedded in all learning areas of pre-service teachers (Enciso, et al, 2017; Olalekan, 2017; Hussin, et al, 2019). However, CTS among prospective teachers and elementary school teachers are still low (Nold, 2017; Pretorius, et al, 2017; Cloete, 2018). Students need to improve their ability to ask, listen, and respond well (Chikeleze, et al, 2018).

There are various patterns to produce higher education graduates who master CTS. Enis (1989) proposes four types of learning approaches to apply CTS, specifically general, infusion, immersion, and mixed-method, that the most effective method for practicing CTS is using a mixed-method (Pnevmatikos, et al, 2019). Tiruneh (2018) proposed five principles in developing learning models to train CTS, i.e. focus of problem, energizing, presentation, covering, and consolidation. Student involvement in a learning environment that supports higher-order thinking activities is the most effective approach to guide them in developing CTS (Hussin et al, 2019).

To instill CTS into learning requires a variety of appropriate learning methods, strategies, and models. A variety of teaching and learning methods are needed to teach CTS (Repo et al, 2017). Previous studies associated with efforts to improve CTS in higher education include the use of science writing heuristics (SWH) for prospective teachers (Poce, et al, 2017); (Hand, et al, 2018), and the use of mind maps (Fuad, et al, 2017). However, no previous studies are found to have been undertaken to foster pre-service elementary school teachers' CTS. The development of models that emphasize simple technology products from science concepts learned has not yet existed. Accordingly, the researchers develop a learning model that combines inquiry processes and technology design according to the science concepts learned to empower pre-service elementary school teachers' CTS in the natural science course. The research question is "how practical and effective is the STLC learning model in empowering pre-service elementary school teachers' CTS in science concept development course?".

Empower Critical Thinking Skills (CTS) For Pre-Service Teacher (PST) Elementary School

Critical thinking is believed by education experts in the world as an absolute skill that must be possessed by prospective teachers in preparing the appropriate generation of their times. Unpredictable acceleration in all fields, rapid changes, and abundant information in cyberspace (big data) characterize the life in the 21st-century (Poce et al., 2017; Ganayem & Zidan, 2018; (Roohr, et al, 2019). Individuals with high adaptability can survive in existing conditions, while those who cannot adapt can be eliminated even extinct. Extinction is not merely physical such as animals or plants that are not able to adapt to environments, but it includes the loss of thought patterns replaced by modern mindsets.

CTS are important to be developed in education (Rahdar, Pourghaz, & Marziyeh, 2018; Cintamulya, 2019) through the educational process as a primary means of preparing students for active and responsible life (Bandyopadhyay & Szostek, 2019). CTS is a major feature of modern education (Karakoc, 2016). This is because CTS cannot necessarily be mastered by someone without continuous efforts in a structured plan prepared by educators (Unlu, 2018; Changwong, et al, 2018). According to Aljaafi (2019), CTS cannot even be taught by only using textbooks but must be ignited through concrete activities such as the ability to investigate, express opinions, respond to the opinions of others, and dare to make decisions.

According to Facione (2016), CTS can be identified in terms of six aspects, namely: interpretation, inference, analysis, explanation, evaluation, and self-regulation. Interpretation is related to one's ability to express the meaning of an object observed. Students can explain definitions contained in data, graphics, events, and criteria. The ability to analyze refers to the ability to identify relationships between observational objects. Inference relates to the ability to determine the elements in concluding. Evaluation is the ability to compare or assess the credibility of an object observed. Explanation is associated with the ability to provide reasoning explanations for an object or event. Self-regulation corresponds to self-awareness to monitor cognitive processes that are passed. CTS does not occur immediately and instantly so that CTS is classified into higher-order thinking skills (HOTS). CTS requires proper mastery of the lower thinking levels such as the abilities to remember, understand, and apply.

According to Tiruneh et al. (2018), there are two effects of CTS. They consist of the effect as near transfer and the effect as far transfer. Near transfer depicts a condition when CTS is applied directly to complete a new task in a learning activity deliberately designed by the teacher. Students' CTS can be trained by solving problems related to daily life (Mahanal, et al, 2019). In the meantime, far transfer portrays a condition when CTS already learned are applied in completing new tasks beyond what is learned in the classroom. To empower CTS, pre-service teachers need to be facilitated in completing new tasks using both near and far transfers.

Science in the Curriculum of PST Elementary School

Science is a compulsory course provided to pre-service teacher elementary school. This is because elementary school teachers teach science in elementary school for six years of students’ learning. The mastery of science concepts becomes absolute because it is a provision throughout the profession. Instilling the right theories from an early age has become a heavy responsibility for pre-service elementary school teachers. Moreover, the figure of an elementary school teacher not only is as a teacher in the classroom but also becomes the second parent throughout the day at school (Purnomo, 2017; Ateş, 2019; Winarno, et al, 2019). Science learning must have the characteristics of inquiry as natural science exists. Through a process of inquiry, science is formed. Therefore, the nature of science is cognitive, process, product, and attitude (Papaevripidou, et al, 2017; Patonah, et al, 2018). If science is presented only as a product, students will stop at the level of remembering. However, when science is taught in its entirety, students will retain experiences, skills, and attitudes. Science is a means of character development.

The process of science is to teach inquiry because the inquiry is the key to learning science. Therefore, it also referred to as the way of thinking (Djamas, et al, 2018; Talanquer, 2019). Science learning is oriented to questions, and questions are used to make observations to get accurate data. The results of observations are verified to generate the truth so they can be easily explained and communicated to draw conclusions. The process of preparation in learning science emphasizes the involvement of students in finding concepts or applying concepts. In such a way, students need to be motivated to experience and discover their natural science concepts. In this case, lecturers need to provide adequate facilities to activate students’ activities in learning through observation and create challenging problems to be solved (Thompson, 2017).

This course gives from the first to six semesters, divided into two parts, Science Concepts (SC) and Science Concept Development (SCD). The SC consists of Measurement, Substances, Acid-base, Heat, Plants, Respiratory system, Solar system, and Herbal plants. The SSD consists of Light, Sound, Electricity, Magnetism, Digestive system, Circulatory system, Earth structure, and Adaptation of living things. Both courses taught as many as three credits for each week consist of classroom activities, laboratory activities, and learning outside.

Science Technlogy Learning Cycle (STLC) Learning Model

Science and inquiry become an inseparable part of science's heart inquiry (Kazempour, 2018). Individuals who study science should be use inquiry. In an interview, students make observations, ask questions, make hypotheses, test hypotheses, draw conclusions, and communicate results. Such stages are exactly what scientists do in discovering science. An inquiry process is a systematic and interrelated reflection process (Thompson, 2017). The advantages of inquiry in science learning include encouraging students to think critically, systematically, and based on facts. These advantages expected to arise in science students. However, the routine activities that are often performed in the laboratory do not guarantee that these benefits are attached to the student after leaving it (Marchut & Gormally, 2019). Students who do inquiry activities have a little chance of getting involved in real-world problems. As a result, the products produced are less suited to the problems they are facing.

Students are showed the concepts learned to the appropriate technology/simple technology products. This kind of activity is a way to motivate and engage students in real-life science and engineering practicess (Applebaum, et al, 2017). However, students' ability to translate scientific concepts into technology is still low (Thompson, 2017). Science and technology in the process of learning science still rest on the theory of science or technology alone (Inouye & Houseal, 2018). In this regard, science is identified with the ability to remember concepts, while technology is indistinguishable with a machine from the scientific process. As a matter of fact, technology can produce new science, and science can bring forth new technology.

A model of learning that can foster critical thinking and caring skills is a Science and Technology Learning Cycle (STLC). This model rests upon constructivist, meaningful, and discovery-based learning concepts. The terms used in the learning syntaxes refer to the components of inquiry developed by Wenning (2011) and the technology learning cycle (TLC) by Marra et al (2004). The specifics of the model developed outside and in the classroom to provide potential teachers with CTS.

The STLC learning model has six syntaxes extending to observation, manipulation, design of applied technology, application, sharing, and writing (Patonah, et al, 2019). The implementation of the six syntaxes is carried out in cycles and in a sequential way as shown in Figure 1. To be able to manipulate, students must observe correctly. Students design simple technology based on observation and manipulation of information. Students apply the design to simple technology products. The whole process of students' activities is presented by a group sharing in front of the classroom, or by visiting each other (windows showing). From the students' activities, it appears that the STLC learning model emphasizes students' collaboration and cooperation within groups. Each group visits other groups to ask about the characteristics of the products and offer suggestions. The final syntax of the STLC model is writing. In so doing, students gather all information gained from the previous stages in the form of scientific writing with the number of words and the amount of time as specified. The STLC learning model is proven to be valid and reliable through validation by eight experts in each field.

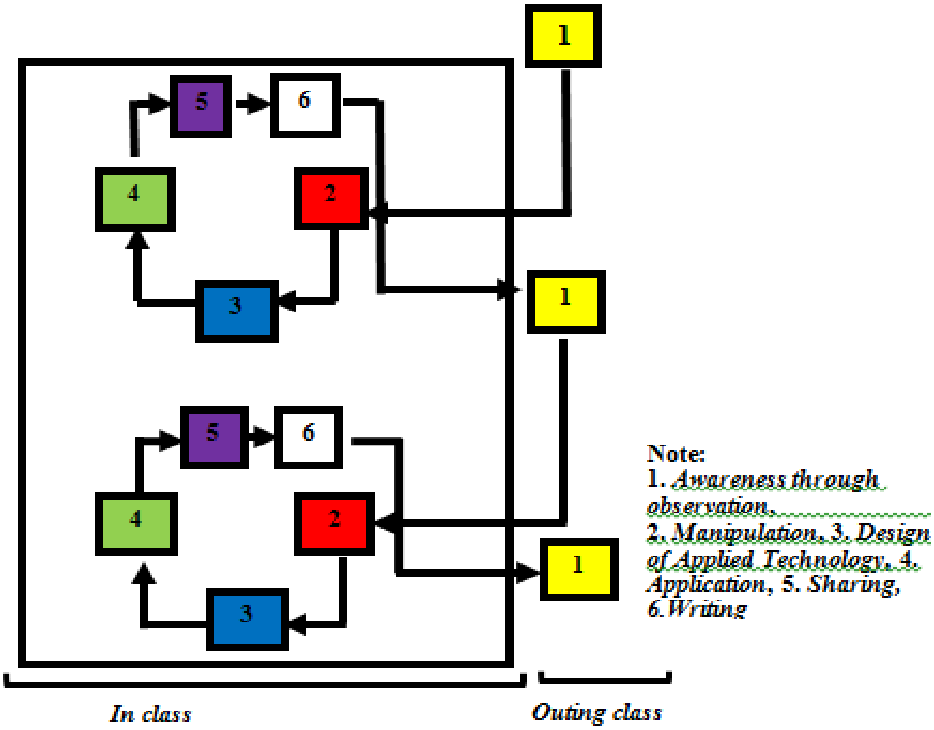


Figure 1
Framework of STLC model learning

The profits of CTS to be empowered by considering the relationship between the syntax of the learning model and aspects of CTS (shown in Table 1).

Table 1
The relationship of each syntax to the achievement of CTS

STLC Syntax (Patonah et al,2018)	CTS Domain (Facione,2016)	Student Activity	Lecturer Activity
Observation	Interpretation (categorization, decoding significance, clarifying meaning)	- Identifying causal factors due to the concept of science. - Participating in observations.	- Presenting the phenomenon of science in the everyday environment. - Directing students to make observations
Manipulation	Analysis (Examining ideas, identifying, and analyzing argument)	- Gathering supporting information to provide solutions. - Analyzing the data.	- Involving students in analyzing the data from observations.
Design of applied technology	Explanation (Justifying procedures)	- Developing appropriate technology designs that will be used to solve environmental problems	- Facilitating students to design appropriate technology that will be used to solve environmental problems according to the theme of the science being discussed.
Application	Inference (drawing conclusion, conjecturing alternative)	- Implementing appropriate technology designs in the form of simple technologies.	- Guiding students to implement appropriate technology designs they choose.
Sharing	Evaluation (assessing claim, assessing argument)	- Presenting information about the technology developed through presentations/window shopping.	- Directing students to present their findings.
Writing	Self-regulation (self-examination, self-correction)	- Compiling scientific papers from the presentation of the technology products that have been presented.	- Guiding students to reveal activities carried out in the form of scientific writing. - Providing feedback on the writing made by the students.

Each syntax has the expected goals and critical thinking skills expected.

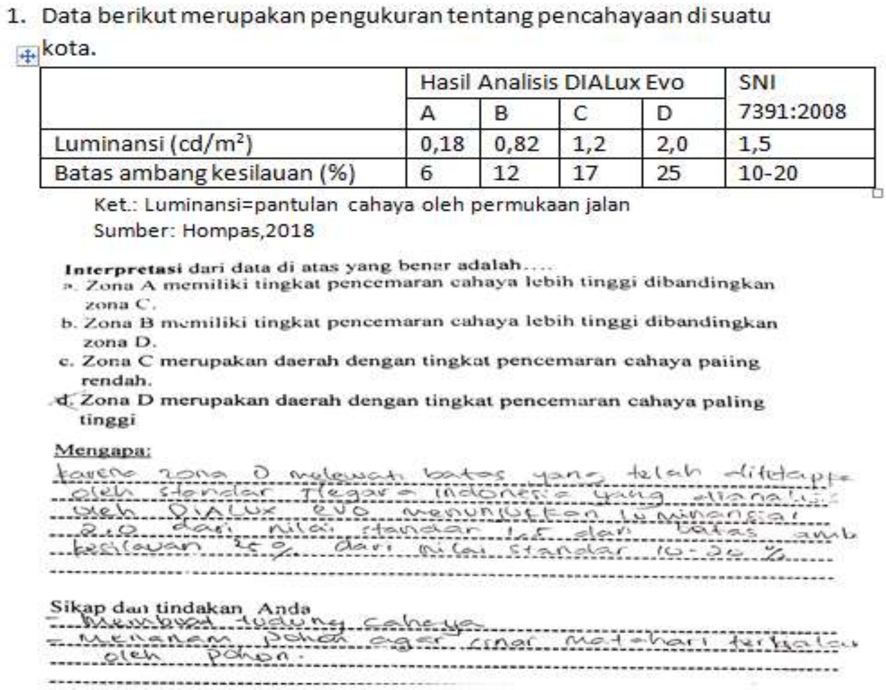
METHOD

Participant

This research was conducted by engaging the second-semester students, in Academic Year 2018/2019, who took SCD courses in elementary teacher education department at PGRI University of Semarang, Central Java, Indonesia, The purpose of this study emphasized the practicality and effectiveness of STLC learning model in empowering CTS. There were four SCD themes used in this study: light, sound, electricity, and magnetism. The number of samples was seventy-three students divided into two classes containing forty-three students (Eks.Class) and thirty-three students (Control Class). They were selected from a total of three hundred and thirty students. This study took place from February-July 2019.

Procedure

This study applied experiment research with pretest-posttest control group design. Initially, students in both experimental and control classes were given a pre-test (O1) of CTS. STLC learning model was applied in the experiment class, and a traditional learning method was implemented in the control class. At the end of learning, the samples from both classes were given a posttest (O2) of CTS. The STLC model was applied repetitively by involving the four themes. The instrument to measure CTS was multiple-choice questions followed by questions that asked for the reasons beyond choosing the answers, beliefs in choosing the answers, and attitude towards the concepts believed. There were five items to represent each of the themes which were used in both pretest and posttest. The question items were developed based on the idea of CTS by Facione (2016). The instrument has validated with an infit range of .77-1.20, mean INFIT MNSQ of .99, SD of .11, and internal consistency of 0.85. The multiple-choice test with four answer choices comes with the right reasons and attitudes (Figure 2).



1. Data berikut merupakan pengukuran tentang pencahayaan di suatu kota.

	Hasil Analisis DIALux Evo				SNI 7391:2008
	A	B	C	D	
Luminansi (cd/m²)	0,18	0,82	1,2	2,0	1,5
Batas ambang kesilauan (%)	6	12	17	25	10-20

Ket.: Luminansi=pantulan cahaya oleh permukaan jalan
Sumber: Hompas,2018

Interpretasi dari data di atas yang benar adalah….
a. Zona A memiliki tingkat pencemaran cahaya lebih tinggi dibandingkan zona C.
b. Zona B memiliki tingkat pencemaran cahaya lebih tinggi dibandingkan zona D.
c. Zona C merupakan daerah dengan tingkat pencemaran cahaya paling rendah.
d. Zona D merupakan daerah dengan tingkat pencemaran cahaya paling tinggi

Mengapa:
karena zona D melewati batas yang telah ditetapkan oleh standar Negara Indonesia yang dianalisis oleh DIALux Evo menunjukkan luminansi 2,0 dari nilai standar 1,5 dan batas amb kesilauan 25% dari nilai standar 10-20 %

Sikap dan tindakan Anda
- Membuat tudung cahaya
- Menanam pohon agar sinar matahari terhalau oleh pohon.

Figure 2
Sample item test

The time to complete each theme is two weeks with three-course credits per week consisting of 150 minutes for face-to-face learning, 180 minutes for structure assignments, and 180 minutes for independent activities. Before the research began, briefing with the model lecturer was initially done concerning things that needed to be prepared and carried out while applying the STLC model. Lecturer received STLC model book, learning module, lesson plans, observational sheets of model implementation, product assessment sheets, sharing assessment and writing assessment sheets, and CTS assessment. The validity and reliability of each instrument were examined. The validity and reliability values are 0.86 (valid) and 85.85 (reliable) for STLC learning module; 0.91 (valid) and 86.66 (reliable) for lesson plans; 0.82 (valid) and 86.38 (reliable) for teaching materials; and 0.87 (expert validation) and 0.85 (internal consistency) for CTS assessment.

Data Analysis

The performance of the model was determined by percentage, referring to the number of the head syntax divided by the whole learning phases and multiplied by 100%, so lecturer and student performances signed by percentage based. The model's performance criteria were determined based on five categories comprising very low (< 24.90%), less (25.00% - 37.50%), medium (37.60% - 62.50%), good (62.60% - 87.50%), and very good (>87.50%). The N-Gain score was defined by the criteria consisting of high (≥ .7), medium (.3 ≤ N-Gain ≤ .7), and low (< .3). To find out a difference between students' CTS in the experimental class and those of the control class, a t-test with the significance of .05 was used. In principle, H0 is accepted if p> .05 and H0 is rejected if p< .05. The t-test was performed using SPSS 21 to accepting or rejecting H0.

The assessment of technology products, products, observations of sharing, and student writing is determined by the scores obtained from the assessment rubric. The score obtained is divided by the maximum score divided by 100 to get a value with four categories: very good (76-100), good (51-75), enough (26-50), and less (less or equal to 25). For the student products in the form of writing, the number of words (50-150 words) is also determinant.

Besides, the data analyzed descriptively were the data concerning the performance of the learning model, the evaluation of simple technology products, the assessment of sharing, and the assessment of writing. Students' responses were analyzed using a Winstep.

FINDINGS

The implementation of the STLC learning model based on the lecturer's activities is shown in Table 2.

Table 2
Implementation of the STLC model in each learning cycle by lecturer

Sintax	The lecturer activity (%)			
	Sound	Light	Electricity	Magnetism
Observation	62.50	75.00	87.50	87.50
Manipulation	50.00	62.50	75.00	87.50
Design of Applied Technology	62.50	62.50	75.00	87.50
Application	50.00	75.00	75.00	75.00
Sharing	50.00	50.00	75.00	87.50
Writing	25.00	50.00	75.00	75.00

According to Table 2, students' activities increased in each of the themes or cycles. In the first cycle, the writing syntax was included in a less category, but, the last cycles, were classified into good and very good categories. The implementation of the STLC learning model based on students' activities (Table 3).

Table 3
Implementation of the STLC learning model in each cycle by students

Sintax	The student activity (%)			
	Light	Sound	Electricity	Magnetism
Observation	50.00	62.50	75.00	88.00
Manipulation	50.00	62.50	75.00	88.00
Design of Applied Technology	37.50	50.00	75.00	88.00
Application	50.00	50.00	75.00	75.00
Sharing	50.00	62.00	62.50	88.00
Writing	25.00	50.00	75.00	75.00

According to Table 3, the activity increased for each theme. In the first cycle, the syntaxes of the design of applied technology and writing were classified into a less category. At the end of the whole cycle, students' activities were categorized as a very good category.

Table 4 shows the assessment result of the simple technology products produced during the learning process. The technology products are associated with the concepts of light, sound, electricity, and magnetism.

Table 4
Evaluation of the technology products

Aspect of assesment	Cycle/Theme			
	Light	Sound	Electricity	Magnetism
Tidy	2.95	3.21	3.00	3.00
Proportional	2.97	2.98	3.00	3.00
Realistic	2.24	3.23	3.61	3.19
Display	3.03	2.81	3.79	3.40
Benefits	2.57	2.37	3.79	3.40
Eco-friendly	2.60	2.40	3.00	3.00
Target rigth	3.11	2.98	3.40	3.40

According to Table 4, the overall aspects of each cycle increased. The assessment result obtained various scores as they related to the levels of assessment aspects that were assigned to the students before the implementation of learning. Table 5 shows students' abilities to exchange information through sharing activities.

Table 5
Result of observation of sharing activity

Aspect of assesment	Cycle/Theme			
	Light	Sound	Electricity	Magnetism
Analysis	2,38	3,00	3,00	3,00
Communicative	3,16	3,00	3,00	3,00
Mastery	2,43	2,37	2,61	2,79

According to Table 5, each cycle experienced fluctuation because students' sharing activities varied according to the task of each group. Table 6 shows the evaluation of students' writing products.

Table 6
Student writing product

Aspect of assesment	Cycle/Theme			
	Light	Sound	Electricity	Magnetism
Relevance	1.66	1.51	2.17	2.15
Equipment	3.44	3.39	3.71	3.10
Cleaniless	3.88	3.27	3.88	3.73
Average number of words	200.49	232.24	131.44	121.05
Maximum number of words	355	390	314	190
Minimum number of words	104	113	72	64

From Table 6, it is known that the related aspects fell into the lowest category for each cycle. The foregoing occurred because students delivered information separately for each technology product produced by each group. Table 7 shows the score gain of each domain of CTS in each cycle.

Table 7
CTS domain score and N-Gain score

	N	Light Theme			Sound Theme			Electricity Theme			Magnetism Theme		
STLC Class		Pre-test	Post-test	N-Gain	Pre-test	Post-test	N-Gain	Pre-test	Post-test	N-Gain	Pre-test	Post-test	N-Gain
Interpretation	43	67.44	95.35	.86	88,37	97.67	.80	53.49	65.12	.25	83.72	97.67	.86
Analysis	43	76.74	81.40	.20	30.23	41.86	.17	72.09	93.02	.75	86.05	97.67	.83
Inference	43	81.40	97.67	.87	18.60	34.88	.20	83.72	97.67	.86	51.16	83.72	.67
Evaluation	43	81.40	86.05	.25	93.02	95.35	.33	79.07	95,67	.78	60.47	88.37	.71
Eksplanation	43	72.09	76.74	.16	81.40	97.67	.87	51.16	79.07	.57	79.07	97.67	.89
Self-regulation	43	76.74	81.40	.20	88.37	97.67	.80	79.07	95.35	.78	79.07	97.67	.89
Control Cllass													
Interpretation	30	73.33	90.00	.63	90.00	96.67	.67	6.67	30.00	.25	73.33	96.67	.88
Analysis	30	16.67	13.33	-.04	30.00	10.00	.29	53.33	80.00	.57	33.33	63.33	.45
Inference	30	73.33	83.33	.38	46.67	63.33	.31	10.00	30.00	.22	50.00	33.33	-.33
Evaluation	30	90.00	90.00	.00	73.33	93.33	.75	86.67	96.67	.75	10.00	73.33	.70
Eksplanation	30	73.33	96.67	.88	80.00	90.00	.50	3.33	16.67	.14	93.33	96.67	.50
Self-regulation	30	16.67	13.33	-.04	46.67	63.33	.31	86.67	96.67	.75	93.33	96.67	.50

From Table 7, it is known that the experiment class has a higher the gain. The independent test was undertaken to measure the effectiveness of the STLC model in empowering CTS (in Table 8).

Table 8
Independent t-test score

Cycle	N-Gain	Independent Samples Test, α= .05					Decision
		Levene's Test for Equality of Variances		t-test for Equality of mean			
		F	Sig.	Sig. (2-tailed)	Mean.Diff	Std. Error Diff.	
1	.42	.289	.593	.000	20.048	4.108	Ho is rejected
2	.53	31.68	.000	.047	8.076	3.990	Ho is rejected
3	.45	17.576	.000	.000	29.261	3.038	Ho is rejected
4	.81	7.842	.007	.000	17.132	3.094	Ho is rejected

From Table 8, that all of the four cycles had a p-value smaller than α, it's mean that there was a difference in CTS between students that learned using STLC model in the experimental class and those that learned using a traditional model in the control class. STLC learning model could empowering students' CTS.

At the end of the research activities, the students were given questionnaires to find out their responses to learning using the STLC model. The whole students' responses are shown in Figure 3

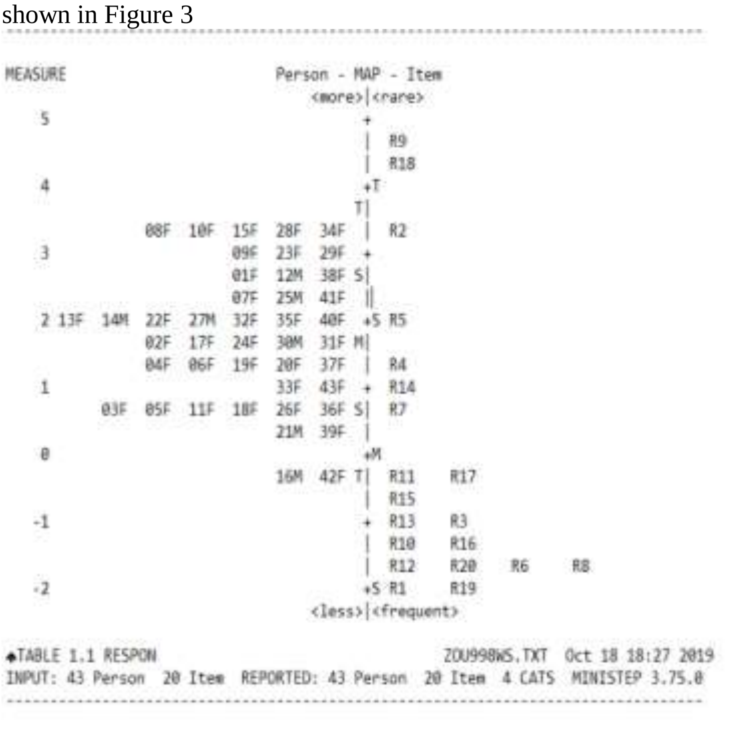


Figure 3
Student responses to STLC learning

Anchored in Figure 3, students could be split into two groups. One group agreed that the STLC model could empower CTS, and the other group disagreed that it could do so.

DISCUSSION

The practicality and effectiveness of the STLC model showed that this model could enhance CTS. The practicality of the STLC model was exhibited by the lecturer and students' activities in learning. The lecturer's activities, as displayed in Table 2, increased in each of the cycles with good and excellent criteria. Like students' activities as presented in Table 3, the students' activities during learning increased in each of the cycles with good and excellent criteria. The syntaxes of the design of applied technology and writing indicated that students' activities had the lowest scores because both were relatively new to students. Aligned with the study conducted by Novak & Wisdom (2018), students' ability to design technology from science products learned is still low. The concepts of science learned so far are still limited to memorizing (Kaitlyn & Kelly, 2018; Hanif, et al, 2019; Hart, 2019; Baguma et al., 2019). On the other hand, scientific writing ability is constrained by the low level of literacy in terms of both reading and writing. Writing skills are also included in the 21-st century skills (Geithner & Pollastro, 2019) and are essential to educational success (NRC, 2015).

Tables 4, 5, and 6 show the evaluation of learning products developed from the concepts of light, sound, electricity, and magnetism. The design of the developed technology was made in a concrete form, and its quality was determined by its neatness, proportionality, realisticity, look, usefulness, eco-friendliness, and effectiveness. At the end of the cycle, all aspects of assessment in technology designed were classified into a very good category. The results of the technology design were communicated to get advice and feedback from other students through sharing. The assessment aspect of sharing ability involved analysis, communication, and mastery of the material. At the end of the cycles, all aspects of the sharing assessment were very good. Students provided information in a well-documented way, and they made connections among sets of information collected from the technology products they produced. The number of words in their scientific papers was circumscribed to support students to make use of qualified words in expressing their ideas in the form of writing. A total of one hundred and fifty words applied in a scientific paper were written out within thirty minutes. According to Table 5, students' writing products increased although the score in the aspect of relevance was still low. Writing is a student's ability to reflect on something that is understood (Bonham, et al, 2018; Geithner & Pollastro, 2019).

The mastery of students' CTS at the end of cycles was demonstrated by the highest N-gain in the domains of exploration and self-regulation, followed by the aspects of interpretation, analysis, and inference (see Table 7). The explanation had a high N-gain (.89) as a sign that students could explain. The information obtained was poured into both direct and indirect sentences. Self-regulation was characterized by a willingness to accept advice and criticism and to be aware of one's condition. Self-regulation has a close relationship with the ability to solve science problems (Aydın, et al, 2019; Lawanto, et al, 2019). N-gain interpretation at the end of the cycle was in a high category (.86), wherein students identified information in the form of graphs and statements as the materials to draw a conclusion. Weaknesses in interpreting data can lead to an incorrect conclusion (Knöchelmann, et al, 2019). Students can analyze data well if there is a relevant source of information available (Lima & Martin, 2018). Analytical ability is a useful linking cognitive function and appropriate physical movement (Fadzil, 2017). Through the STLC learning model for prospective school teacher can empower CTS. Based on the aspects of critical thinking, the STLC learning model mainly empowering the dominance of interpretation, inference, explanation, and self-regulation. The analysis and evaluation is a domain that is difficult to use in the themes of light, sound, and electricity. However, on the magnetic theme, all domains of CTS can be empowered. In contrast to the experimental class, n-gain scores tend to be in a low category. The overall N-gain score in the STLC class was higher than that of the control class.

To define the effectiveness of the STLC model in empowering CTS, each cycle or theme was analyzed using an Independent t-test as shown in Table 7. With a significant level of .05, all cycles had p values smaller than .05, which rejected the null hypothesis. Thus, it could be concluded that there was a difference in CTS after applying the STLC model. The STLC learning model as an alternative in empowering CTS for prospective teachers.

Students give a good response (95%) to use the STLC model to empower critical thinking skills and environmental care (see Figure 3). As the foregoing, students were happy as well as more motivated and had a high degree of empathy for the surrounding environment. Only 5% of the students said otherwise because they had difficulties in interacting with the team.

CONCLUSION

Based on the results and discussion, we conclude that the STLC learning model is practical to be applied and effective to empower CTS. The practicality is indicated by the activities of the lecturer and students in good and very good categories. The effectiveness of the STLC model in empowering CTS sis seen from the high-category N-gain, p-value at each cycle/theme < 05, and student responses that agree with the STLC model to empower CTS. Students experience the benefits of SCD learning to produce simple technology in contributing to solving problems around them. We recommended: 1) to investigate the domain of CTS in-depth, 2) to develop IT-based learning media to support optimal results, and 3) to apply the STLC learning model in allied subjects in empowering CTS. This research implies that the STLC learning model as an alternative learning model that can empower critical thinking skills at various levels of education, especially in preparing teacher candidates.

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REFERENCES

Ab Kadir, M. A. (2017). What Teacher Knowledge Matters in Effectively Developing Critical Thinkers in the 21 st Century Curriculum? *Thinking Skills and Creativity*, *23*, 79–90. https://doi.org/10.1016/j.tsc.2016.10.011

Ahmatika, D. (2017). Peningkatan Kemampuan Berpikir Kritis Siswa Dengan Pendekatan Inquiry/Discovery. *Euclid*, *3*(1), 394–403. https://doi.org/10.33603/e.v3i1.324

AlJaafi, E., & Şahin, M. (2019). Critical Thinking Skills for Primary Education: the Case in Lebanon. *Turquoise International Journal of Educational Research and Social Studies*, *1*(1), 1–7.

Applebaum, L. R., Vitale, J. M., Gerard, E., & Linn, M. C. (2017). Comparing design constraints to support learning in technology-guided inquiry projects. *Educational Technology and Society*, *20*(4), 179–190.

Ateş, Ö. (2019). Preservice Teachers' Views of Nature of Science and Their Metaphoric Perceptions of Science and Scientists. *International Online Journal of Educational Sciences*, *11*(4), 141–159. https://doi.org/10.15345/iojes.2019.04.011

Aydın, B., Memnun, D. S., Dinç, E., Arsuk, S., & Meriç, H. (2019). A Study on the Relationship Between Seventh-Grade Students' Self-Regulation Skills and Their Problem-Solving Achievements. *Journal of Educational Issues*, *5*(1), 71. https://doi.org/10.5296/jei.v5i1.14543

Baguma, R., Bagarukayo, E., Namubiru, P., Brown, C., & Mayisela, T. (2019). Using WhatsApp in Teaching to Develop Higher Order Thinking Skills--A Literature Review Using the Activity Theory Lens. *International Journal of Education and Development Using Information and Communication Technology*, *15*(2), 98–116.

Bandyopadhyay, S., & Szostek, J. (2019). Thinking critically about critical thinking: Assessing critical thinking of business students using multiple measures. *Journal of Education for Business*, *94*(4), 259–270. https://doi.org/10.1080/08832323.2018.1524355

Bonham, S. W., Jones, K., Luna, B., & Pauley, L. (2018). An integrated model for teaching management skills. *Journal of Management Education*, *20*(2), 40–47. https://doi.org/10.1177/105256299602000202

Caudle, L., & Paulsen, T. H. (2017). Evidence of Critical Thinking in a Capstone Course: A Historical Perspective 1. *NACTA Journal*, *61*(3), 208–218. Retrieved from http://search.proquest.com/docview/2001047296/

Changwong, K., Sukkamart, A., & Sisan, B. (2018). Critical thinking skill development: Analysis of a new learning management model for Thai high schools. *Journal of International Studies*, *11*(2), 37–48. https://doi.org/10.14254/2071-8330.2018/11-2/3

Chikeleze, M., Johnson, I., & Gibson, T. (2018). Let's Argue: Using Debate to Teach

Critical Thinking and Communication Skills to Future Leaders. *Journal of Leadership Education*, *17*(2), 123–137. https://doi.org/10.12806/v17/i2/a4

Cintamulya, I. (2019). Analysis of students' critical thinking skills with reflective and impulsive cognitive styles on conservation and environmental knowledge learning. *Asia-Pacific Forum on Science Learning and Teaching*, *20*(1), 1–15.

Cloete, M. (2018). The impact of an integrated assessment on the critical thinking skills of first-year university students. *Accounting Education*, *27*(5), 479–494. https://doi.org/10.1080/09639284.2018.1501717

Djamas, D., Tinedi, V., & Yohandri. (2018). Development of interactive multimedia learning materials for improving critical thinking skills. *International Journal of Information and Communication Technology Education*, *14*(4), 66–84. https://doi.org/10.4018/IJICTE.2018100105

Ennis, R. H. (1989). Critical Thinking and Subject Specificity: Clarification and Needed Research. *Educational Researcher*, *18*(3), 4–10. https://doi.org/10.3102/0013189X018003004

Facione, P. A. (2016). *Critical Thinking : What It Is and Why It Counts*.

Fadzil, H. M. (2017). Exploring Students ' Acquisition of Manipulative Skills during Science Practical Work, *8223*(8), 4591–4607. https://doi.org/10.12973/eurasia.2017.00953a

Fuad, N. M., Zubaidah, S., Mahanal, S., & Suarsini, E. (2017). Improving junior high schools' critical thinking skills based on test three different models of learning. *International Journal of Instruction*, *10*(1), 101–116. https://doi.org/10.12973/iji.2017.1017a

Ganayem, A., & Zidan, W. (2018). 21st CENTURY SKILLS: STUDENT PERCEPTION OF ONLINE INSTRUCTOR ROLE. *Interdisiplinary Journal of E-Skills and Lifelong Learning*, *14*(10), 1–16.

Geithner, C. A., & Pollastro, A. N. (2019). Doing peer review and receiving feedback : impact on scientific literacy and writing skills, 38–46. https://doi.org/10.1152/advan.00071.2015

Hand, B., Shelley, M. C., Laugerman, M., Fostvedt, L., & Therrien, W. (2018). Improving critical thinking growth for disadvantaged groups within elementary school science: A randomized controlled trial using the Science Writing Heuristic approach. *Science Education*, *102*(4), 693–710. https://doi.org/10.1002/sce.21341

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. *Journal of Science Learning*, *2*(2), 50. https://doi.org/10.17509/jsl.v2i2.13271

Hart, J. (2019). Interdisciplinary project-based learning as a means of developing employability skills in undergraduate science degree programs. *Journal of Teaching and*

Learning for Graduate Employability, *10*(2), 50–66. https://doi.org/10.21153/jtlge2019vol10no2art827

Heft, I. E., & Scharff, L. F. V. (2017). Aligning best practices to develop targeted critical thinking skills and habits. *Journal of the Scholarship of Teaching and Learning*, *17*(3), 48–67. https://doi.org/10.14434/v17i3.22600

Hussin, W. N. T. W., Harun, J., & Shukor, N. A. (2019). Online interaction in social learning environment towards critical thinking skill: A framework. *Journal of Technology and Science Education*, *9*(1), 4–12. https://doi.org/10.3926/jotse.544

Inouye, M., & Houseal, A. (2018). Reawakening the Past—Capitalizing on a Swinging Pendulum: Emphasizing the Foundational Skills of Critical Thinking in the Classroom. *Schools*, *15*(1), 140–148. https://doi.org/10.1086/697098

Kaitlyn, B. Y., & Kelly, M. (2018). Making science memorable. *Science for All*, *March*, 26–29.

Karakoc, M. (2016). The significance of critical thinking ability in terms of education. *International Journal of Humanities and Social Science*, *6*(7), 81–84. Retrieved from http://www.ijhssnet.com/journals/Vol_6_No_7_July_2016/10.pdf

Kazempour, M. (2018). Elementary Preservice Teachers' Authentic Inquiry Experiences and Reflections: A Multicase Study. *Journal of Science Teacher Education*, *29*(7), 644–663. https://doi.org/10.1080/1046560X.2018.1487201

Knöchelmann, N., Krueger, S., Flack, A., & Osterhaus, C. (2019). Adults' ability to interpret covariation data presented in bar graphs depends on the context of the problem. *Frontline Learning Research*, *7*(4), 58–65. https://doi.org/10.14786/flr.v7i4.471

Kusumoto, Y. (2018). Enhancing critical thinking through active learning. *Language Learning in Higher Education*, *8*(1), 45–63. https://doi.org/10.1515/cercles-2018-0003

Lawanto, O., Febrian, A., Butler, D., & Mina, M. (2019). Self-Regulation Strategies in an Engineering Design Project. *International Education Studies*, *12*(5), 133. https://doi.org/10.5539/ies.v12n5p133

Lima, M. S. De, & Martin, V. A. F. (2018). What's That Object? Learning Astronomical Concepts Through The Use Of The, *5*(1), 23–52.

Mahanal, S., Tendrita, M., Ramadhan, F., Ismirawati, N., & Zubaidah, S. (2019). The Analysis of Students' Critical Thinking Skills on Biology Subject. *Anatolian Journal of Education*, *2*(2). https://doi.org/10.29333/aje.2017.223a

Marchut, A. E., & Gormally, C. (2019). Successes and Limitations of Inquiry-Based Laboratories on Affective Learning Outcomes for Deaf, Hard-of-Hearing, and Hearing Signing Students. *Journal of the Scholarship of Teaching and Learning*, *19*(4), 18–31. https://doi.org/10.14434/josotl.v19i4.24469

Marra, R. M., Howland, J., Jonassen, D. H., & Wedman, J. (2004). Validating the technology learning cycle in the context of faculty adoption of integrated uses of technology in a teacher education curriculum. *Learning*, *1*(1).

Mustofa, & Yuwana, H. S. (2016). The Development of Appreciation Learning Model of Indonesia Literature Based Critical Discourse Analysis to Improve the Students' Critical Thinking Skill. *Journal of Education and Practice*, *7*(33), 166–175. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1122614&site=ehost-live

Nold, H. (2017). Using Critical Thinking Teaching Methods to Increase Student Success: An Action Research Project. *International Journal of Teaching and Learning in Higher Education*, *29*(1), 17–32.

Novak, E., & Wisdom, S. (2018). Effects of 3D Printing Project-based Learning on Preservice Elementary Teachers' Science Attitudes, Science Content Knowledge, and Anxiety About Teaching Science. *Journal of Science Education and Technology*, *27*(5), 412–432. https://doi.org/10.1007/s10956-018-9733-5

NRC. (2015). *Guide to Implementing the Next Generation Science Standards*. https://doi.org/10.17226/18802

Olalekan, M. (2017). Critical Thinking in Nigeria's Pre-Service Teachers Education: A Philosophical Investigation. *Journal of Teacher Education and Educators*, *6*(2), 205–221.

Papaevripidou, M., Irakleous, M., & Zacharia, Z. (2017). Using Teachers' Inquiry-Oriented Curriculum Materials as a Means to Examine Their Pedagogical Design Capacity and Pedagogical Content Knowledge for Inquiry-Based Learning. *Science Education International*, *28*(4), 271–292.

Patonah, S., Nuvitalia, D., & Saptaningrum, E. (2018). Content analysis of science material in junior school-based inquiry and science process skills. In *Journal of Physics: Conference Series* (Vol. 983). https://doi.org/10.1088/1742-6596/983/1/012167

Patonah, Siti. (2019). Designing of Model Science Technology Learning Cycle (STLC) based Material Teaching to Enhance Student Critical Thinking and Environmental Awareness, *330*(Iceri 2018), 234–238.

Pnevmatikos, D., Christodoulou, P., & Georgiadou, T. (2019). Promoting critical thinking in higher education through the values and knowledge education (VaKE) method. *Studies in Higher Education*, *44*(5), 892–901. https://doi.org/10.1080/03075079.2019.1586340

Poce, A., Agrusti, F., & Re, M. R. (2017). ENHANCING HIGHER EDUCATION STUDENTS ' XXI CENTURY SKILLS THROUGH CO-WRITING ACTIVITIES. *Journal of E-Learning and Knowledge Society*, *13*, 51–64.

Pretorius, L., van Mourik, G., & Barratt, C. (2017). Student Choice and Higher-Order Thinking: Using a Novel Flexible Assessment Regime Combined with Critical Thinking Activities to Encourage the Development of Higher Order Thinking. *International*

Journal of Teaching and Learning in Higher Education, *29*(2), 389–401.

Purnomo, Y. W. (2017). The complex relationship between teachers' mathematics-related beliefs and their practices in mathematics class. *New Educational Review*, *47*(1), 200–210. https://doi.org/10.15804/tner.2017.47.1.16

Rahdar, A., Pourghaz, A., & Marziyeh, A. (2018). The impact of teaching philosophy for children on critical openness and reflective skepticism in developing critical thinking and self-efficacy. *International Journal of Instruction*, *11*(3), 539–556. https://doi.org/10.12973/iji.2018.11337a

Repo, S., Lehtinen, T., Rusanen, E., & Hyytinen, H. (2017). Prior education of Open University students contributes to their capability in critical thinking. *Journal of Adult and Continuing Education*, *23*(1), 61–77. https://doi.org/10.1177/1477971417693416

Roohr, K., Olivera-Aguilar, M., Ling, G., & Rikoon, S. (2019). A multi-level modeling approach to investigating students' critical thinking at higher education institutions. *Assessment and Evaluation in Higher Education*, *44*(6), 946–960. https://doi.org/10.1080/02602938.2018.1556776

Rusmansyah, Yuanita, L., Ibrahim, M., Isnawati, & Prahani, B. K. (2019). Innovative chemistry learning model: Improving the critical thinking skill and self-efficacy of pre-service chemistry teachers. *Journal of Technology and Science Education*, *9*(1), 59–76. https://doi.org/10.3926/jotse.555

Schendel, R., & Tolmie, A. (2017). Beyond translation: adapting a performance-task-based assessment of critical thinking ability for use in Rwanda. *Assessment and Evaluation in Higher Education*, *42*(5), 673–689. https://doi.org/10.1080/02602938.2016.1177484

Talanquer, V. (2019). Idea Bank: Crosscutting Concepts as Productive Ways of Thinking. *The Science Teacher*, *087*(02), 16–19. https://doi.org/10.2505/4/tst19_087_02_16

Thompson, T. (2017). Teaching Creativity Through Inquiry Science. *Gifted Child Today*, *40*(1), 29–42. https://doi.org/10.1177/1076217516675863

Tiruneh, D. T., Gu, X., De Cock, M., & Elen, J. (2018). Systematic design of domain-specific instruction on near and far transfer of critical thinking skills. *International Journal of Educational Research*, *87*(October 2017), 1–11. https://doi.org/10.1016/j.ijer.2017.10.005

Unlu, S. (2018). Eurasian Journal of Educational Research Curriculum Development Study for Teacher Education Supporting Critical Thinking* A R T I C L E I N F O. *Eurasian Journal of Educational Research*, *76*(May), 165–186. https://doi.org/10.14689/ejer.2018.76.9

Uribe-Enciso, O. L., Uribe-Enciso, D. S., & Vargas-Daza, M. D. P. (2017). Pensamiento crítico y su importancia en la educación: algunas reflexiones. *Expresiones, Revista Estudiantil de Investigación*, *19*(34), 78–88.

https://doi.org/10.16925/ra.v19i34.2144

Vista, A., Kim, H., & Care, E. (2018). Use of data from 21st century skills assessments: Issues and key principles OPTIMIZING ASSESSMENT FOR ALL USE OF DATA FROM 21ST CENTURY SKILLS ASSESSMENTS: ISSUES AND KEY PRINCIPLES, (October).

Wenning, C. J. (2011). The Levels of Inquiry Model of Science Teaching Wenning (2010) for explications of real-world applications component of the Inquiry Spectrum.) A Levels of Inquiry Redux. *J. Phys. Tchr. Educ. Online*, *6*(2), 9–16.

Wilcox, D., Liu, J. C., Thall, J., & Howley, T. (2017). Integration of Teaching Practice for Students' 21st Century Skills: Faculty Practice and Perception. *International Journal of Technology in Teaching and Learning*, *13*(2), 55–77.

Winarno, Zuhri, M., Mansur, Sutomo, I., & Widhyahrini, K. (2019). Development of assessment for the learning of the humanistic model to improve evaluation of elementary school mathematics. *International Journal of Instruction*, *12*(4), 49–64. https://doi.org/10.29333/iji.2019.1244a