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Improved Understanding of Science Concepts in Terms of the Pattern of Concept Maps Based on Scientific Literacy in Prospective Elementary School Teacher Students

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Abstract. Concept maps are a technique that can represent the knowledge possessed by students. Depiction through concept maps can form a structured and systematic understanding of concepts based on the relationships between the written concepts. In a period of online learning like this, an exciting learning strategy is needed. Therefore, using concept maps can be an alternative learning strategy that lecturers can apply in online learning. This study aims to identify various concept map patterns that students often use to improve conceptual understanding of the topic of global warming as well as increase students' conceptual understanding of the draft concept map patterns. This research is a mixed-method type with concurrent embedded with 83 students of Primary Teacher Education semester 2 of the 2019/2020 academic year. The instrument used was the measurement instrument for the concept map pattern and the measurement of the conceptual understanding test based on scientific literacy for students. The results were then analyzed by normalized N-Gain test and qualitative data analysis. The results showed that students' concept map patterns to improve conceptual understanding using the hub/spokes concept map pattern were 87.9%. Meanwhile, the results of the N-Gain analysis showed several 0.53 (in the medium category), which means that understanding of the concept increases with the application of concept map learning. The concept map pattern that appears depicts the results of the visualization of students' conceptual understanding.
Keywords: Science Literacy; Conceptual Map; Online Learning

Introduction

Science learning deals with the concept and how students systematically find information about natural phenomena. Thus, science materials are not a set of theories. This learning process could develop the targeted achievement by the students in a certain period. The success of the learning process has to do with the teaching methods used by educators (Agustin et al., 2018). During the COVID-19 pandemic, students are demanded to be more autonomous in the learning process and understand the concepts, principles, or theories related to science. The knowledge construction process could be done by applying a conceptual map. A conceptual map could facilitate the knowledge integration process (Schwendimann & Linn, 2016). Concept maps require students to map concepts, and then the idea itself is illustrated by students in the form of graphic illustrations (Lestari et al., 2019). With this conceptual map, students could visualize, produce, and differ the existing correlation, combine several missing ideas and strong potentials (Hamza & Wickman, 2013; Schwendimann, 2015), and have various products (Ruiz-Primo, 2000). Trowbridge & Wandersee (1998) revealed that concept mapping is a productive activity but is often used as an opportunity for summative assessment. A concept map is defined as a graphical tool for organizing and representing knowledge that includes concepts, the relationship between concepts is shown by a connecting line connecting two concepts hierarchically with the most inclusive and specific concepts placed at the top of the map, and the concepts below are sorted into concepts that are less inclusive (Novak & Canas, 2008; Sari et al. 2018).

Several characters of the conceptual map, by Novak & Canas (2008), are 1) conceptual map with hierarchical representation that has the most inclusive and common matters put on the top of the map while the specific matters are put lower of the map; 2) a conceptual map that attaches the cross-link and correlation among the concepts at each different segment or domain of the concept to make it meaningful. Thus, this map can represent creative and critical thoughts with a new cross-link correlation characterization. This visual representation consists of related ideas and connection achievement in a conceptual map. It can facilitate the knowledge-integrated process (Shavelson et al., 2005; Schwendimann & Linn, 2016). The obtained knowledge by students would be meaningful when it is assimilated among the new concepts, propositions, and proportional framework in an individual's cognitive structure. The following characteristic, 3) is a conceptual map with the principal or common concepts on the top part of the map; 4) a conceptual map with a proposition, a statement about a conceptual correlation (information) with the other concept. It consists of two or more related concepts with connectors or connecting phrases to create a meaningful statement; 5) a conceptual map with more specific examples to clarify the intention of the written concepts (Zubaidah et al., 2020). Therefore, the conceptual understanding development by students is important to arrange a science literacy-based conceptual map. Fakhriyah et al. (2017) revealed that each individual demanded science literacy. It consisted of knowledge, scientific process skill, and scientific attitude. It was in line with Masfuah & Fakhriyah (2017), who found that science literacy was a skill to understand science and its daily life implementation. Learning based on science literacy could make learners solve problems based on scientific skills.

They could arrange the conceptual map based on science literacy when they had a full conceptual understanding. Thus, the assimilation of knowledge, context, and scientific skills into the arranged conceptual map. As mentioned by Pailai et al. (2017), Concept maps are the right formative assessment strategy because their characteristics can respond to the need for formative assessment strategies that adequately represent the instructor's expectations and the understanding of students clearly. Jurecki & Wander (2012) stated that students had to have reviewing skills of each life feature critically and scientifically to improve science literacy. It was empirically supported to use of conceptual mapping to enhance, maintain, and develop knowledge (Davies, 2010). According to Fakhriyah et al. (2017), the reality in the field showed that the science literacy level of the Primary School Education Program students was mainly at a nominal level, 66.2%, and a functional level, 33.8%. The students had the concepts to connect science and other science disciplines based on the data. They could write the scientific terms, although they still had misunderstandings.

On the other hand, 33.8% of students could understand the theory and explain the concept correctly. However, their understanding of connecting ideas with their argument was still limited. Thus, science literacy-based learning with the conceptual map as the product was expected to facilitate students to have a better and more meaningful conceptual understanding. The conceptual map is different from mind mapping (Åhlberg 2004, 2013; Slotte & Lonka, 1999). There were only slight differences between mind mapping and conceptual mapping. A conceptual map has a more structured conceptual map with lesser pictures. Thus, it creates a spontaneous association between the elements and explains the inter-idea connection (Davies, 2011). One of the students' stages in arranging the conceptual map was reading the materials or conceptual knowledge. Thus, they could understand the written concept (Mahanal et al., 2016). Then, the students could arrange the conceptual map based on the information they read while reading the concept (Pangestuti et al., 2014). In science, conceptual learning with global warming as the topic could be seen from various perspectives and thoughts. The learning based on science literacy describes the concepts via the conceptual map. It could create a more structured and systematic conceptual understanding based on the written inter-conceptual connection. Danieal et al. (2015) mentioned that a conceptual map could be used as a training method for students to connect the new information with their background knowledge to create meaningful learning and improve science literacy. The conceptual map variety could be grouped based on the writing system of the ordinary and specific concepts based on the students' understanding. Yin et al. (2005) group the conceptual map into linear, circular, hub/spokes, tree, and network or net. The students could arrange their conceptual map based on conceptual and creative understanding. The characteristics of each conceptual mapping model are different. They could be differed from:

a. The linear conceptual model is arranged hierarchically based on several levels. The concepts in the conceptual map are arranged top-to-down or general-to-specific without any branches at each level. This model is usually applied for materials whose concepts are not integrated with other concepts. The concepts in the conceptual map can be understood if the map is read completely.
b. The circular conceptual model seems like a circular pattern. The concepts of this model are arranged in a connected manner. It seems like a chain, but the conceptual map's writing is not ended; even the latest conceptual map is left blank. Thus, connecting the latest concept with the main concept or the initial concept needs to be added with a connector or connecting phrases.
c. The hub/spoke conceptual map is arranged similarly to a spider web. It is drawn from the centre into the sides. The main concept is put in the centre, while the specific concepts are put around the main concept.
d. The tree-conceptual model seems like the linear model. However, this conceptual map model has branches showing the inter-conceptual connections.
e. Network or net conceptual map This model has a complex inter-conceptual connection because, hierarchically, they are built from several levels (Kinchin, 2000).

Self-development and independent learning of students significantly affect the pattern of concept mapping compiled by students. The student's knowledge of environmental pollution could be developed with online science literacy-based learning. During this online learning period, due to the COVID-19 pandemic, an attractive learning strategy is needed to improve the students' learning autonomy. Utami and Yulianto (2020) revealed that the learning model used by a teacher is a factor that supports the success of learning during the process of teaching and learning activities. Concept maps can be said as a way to facilitate organizing information. The use of concept maps in learning activities allows students to process the information obtained through drafting concept mapping and discussion. According to Moore et al. (2011); Singh & Thurman (2019), online learning is learning with an internet connection. Thus, it has accessibility, connectivity, flexibility, and interactivity of various learning interactions. Therefore, learning with a conceptual map could be an alternative learning strategy for the lecturers during online learning. Students could also upload the product of the conceptual map via their personal social media platforms, such as Instagram. Thus, students would access their social media frequently for the learning process and share their opinions or arguments they made in the conceptual map. Kim et al. (2016) revealed that students accessed social media to express themselves, create friendship connections, and build opinions. This research aims to identify the variety of conceptual map patterns applied by the Primary School Education program students to improve their conceptual understanding of environmental pollution topics and improve their conceptual understanding of the arranged conceptual map patterns.

Methods

This research is a part of preliminary research to develop *subject-specific pedagogy* (SSP) within the TPACK framework for the Primary School Education program students. The preliminary research is mix-method research with concurrent embedded design. Cresswell (2016) revealed that mix-method research combined two approaches simultaneously (qualitative and quantitative). On the other hand, the applied combination by the researcher was a concurrent embedded design (see Fig. 1). It was because the quantitative and qualitative research method implementations were done simultaneously with the different propositions of the methods. Quantitative methods measure students' conceptual understanding using test instruments with a one-group pretest-posttest design, while qualitative methods analyze the concept map patterns produced by students using product assessment instruments and interviews to measure student responses.

The research sample was taken using a purposive sampling technique, totalling two classes or 83 PGSD students in semester 2 in the 2019/2020 academic year, totalling eight classes with class criteria with low average learning outcomes. The concept understanding test instrument was given to students to measure their conceptual understanding based on the theory of Yusuf et al. (2020) with indicators 1) restating a concept, 2) grouping objects according to certain properties, 3) giving examples and non-examples of concepts, 4) presenting concepts in various forms, 5) developing necessary or sufficient conditions for a concept, 6) use, utilize and select certain procedures, and 7) apply the concept of problem-solving. This test instrument is given during the pretest and posttest. Meanwhile, the variety of student concept understanding is measured by product assessment and interviews with indicators of concept correctness, the suitability of how to write concepts uploaded to social media with explanatory captions that help readers understand the concept mapping, how to visualize opinions in concept mapping, and models that have been compiled by students, which are divided into five concept map models, namely Linear, Circular, Hub/Spokes, Tree, and Net/Network (Yin et al. 2005). After that, at the end of the meeting, students were given a response questionnaire about the online learning that was carried out. Before being used, the test instrument and product assessment were validated by two experts who showed a very valid category with a score of (92.5) and then used for research. The treatment given is in the form of a concept understanding pretest, mind mapping learning, and student projects to make mind mapping based on the concepts understood. At the end of the lesson, students are given posttest questions, and the concept maps that have been made and interviews are analyzed to see a portrait of their understanding of the concept. Data analysis begins with a normality test, paired t-test pretest and posttest, and gain test to increase understanding of concepts. Meanwhile, the various concept maps were analyzed qualitatively by comparing the student concept maps with the assessment rubrics that have been determined. Furthermore, based on the results of the analysis of the product assessment criteria, it is concluded that various student concept maps are based on a qualitative analysis process that includes data reduction, data presentation, and conclusions (Miles et al., 2014).

The subjects consisted of 83 students of Primary School Education programs from the second semester in the academic year 2019/2020. The sampling technique used is purposive sampling. The data collection techniques were test and non-test. The applied test technique measured the conceptual understanding based on science literacy. The applied instruments were conceptual understanding test measurements based on science literacy for the students. The measurements were then analyzed with a normalized N-Gain test. This research applied a one-group pretest-posttest with the normalized N-gain inferential statistic calculation in the quantitative research stage. Then, the qualitative data was obtained from the conceptual map variety. It was analyzed with an observational sheet completed with adequacy rubrics of conceptual writing in the conceptual map and the applied variety of the students to visualize their opinions. The variety or recognized conceptual map pattern was made by checking the products or the conceptual map results. The students uploaded them on their social media. The conceptual map variety could be grouped into five conceptual map models (Yin et al., 2005). It is grouped into linear, circular, hub/spoke, tree, and net or network. The measurement instruments of the conceptual map pattern could be seen from the arranged model by the students. The conceptual appropriateness written and uploaded by the students with clear caption facilitated readers to understand.

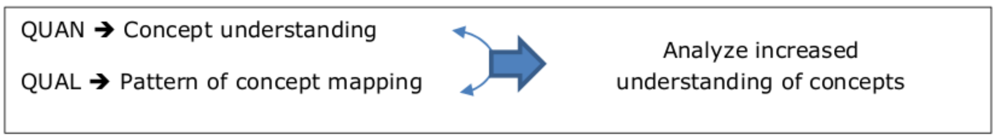

Figure 1. Concurrent embedded design in this research

The findings of the quantitative research stage were taken with *one group pretest-posttest* design. The initial measurement, the *pretest*, was done before applying a science literacy-based conceptual map. On the other hand, the posttest was given after the implementation. The pretest and posttest results were then tested with normalized, paired-t, and N-gain tests.

The normality test of pretest and posttest results showed 83 data had a normal distribution. It can be seen in this Table 1.

Table 1. the Normality Test Results of Pretest and Posttest Data

Variety	Pretest	Postest
X^2_{count}	40.61	33.24
X^2_{table}	12.59	12.59
Criteria	Normally distributed data	Normally distributed data

After the normality test results showed the data were normally distributed, the next test was the paired t-test. This test was used to check whether the hypotheses were accepted or denied. The accepted hypothesis was symbolized with H_0, meaning there was no significant improvement in conceptual understanding between the pretest and the posttest based on science literacy. On the other hand, H_1 symbolized a significant improvement in science literacy-based conceptual understanding of the tests. The paired t-test results can be seen in Table 2.

Table 2. the paired t-test results

Variety	Pretest	Postest
The highest score	78.00	88.00
The lowest score	40.00	70.00
Number (n)	83	83
t_{count}	14,52	Criteria: the average scores of the students' conceptual understanding after the posttest

The paired t-test of both tests showed that H_0 was denied and H_1 was accepted. It was because of the $t_{count} > t_{table}$, meaning there was a significant improvement in conceptual understanding between the tests' scores based on science literacy. The science conceptual understanding promoted science literacy skills (Allchin, 2014). Therefore, if students had excellent conceptual understanding, their science literacy skills would also be better (Masfuah & Fakhriyah, 2017). Besides that, the data could be tested with a normalized N-Gain test. The normalized N-gain calculation results could be grouped into three categories (Table 3).

Table 3. N-Gain score groups

The N-Gain score	**Categories**
g> 0,7	High
0,3≤g≤0,7	Moderate
g < 0,3	Low

The N-gain result showed a score of 0.53 (moderate category). There was a conceptual understanding improvement by applying conceptual map learning based on science literacy. However, according to the average percentage, the condition was less effective based on the N-gain effectiveness interpretation (see Table 4).

Table 4. The N-Gain effectiveness interpretation categories

Effectiveness (%)	**Interpretation**
<40	Ineffective
40-55	Less effective
56-75	Sufficiently effective
>76	Effective

The achievements of conceptual mapping learning could improve the students' conceptual understanding based on science literacy. It can be seen in Figure 2.

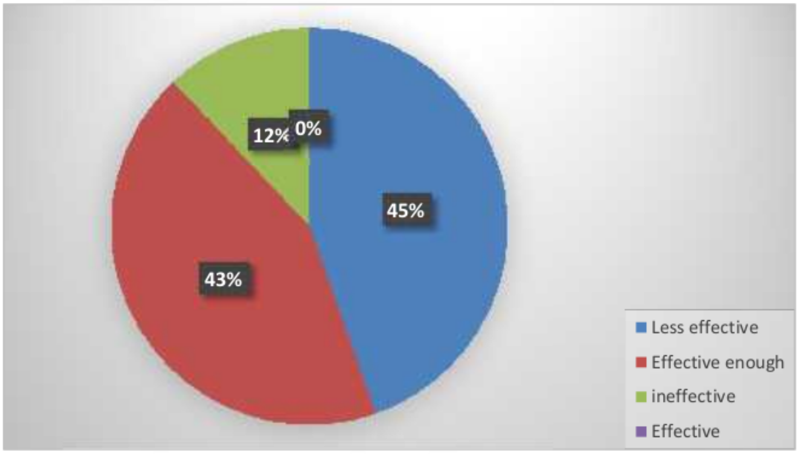

Figure 2. The Conceptual Mapping Learning Achievements toward the Conceptual Understanding based on Science Literacy

This finding shows that the N-gain, 43% of the students, is categorized as sufficiently effective, 45% of the students categorized as less effective, and 12% of students categorized as ineffective. The highest percentage was in the less effective category based on the data. It was because the learning was promoted online that the concepts provided by the lecturers were brief. Thus, the students' readings were low and made them difficult to make a conceptual map. Istarani (2011) emphasized this finding, and she found that the weaknesses of conceptual map learning were a lack of reading materials for students, difficulties for the students to create conceptual maps due to lack of reading materials, and difficulties in thinking concretely while composing the conceptual map. Won et al. (2017) revealed that concept maps in learning have limitations as an assessment tool. This concept map is only a partial representation of the student's concept. The students' other difficulties were the adaptation from each learning stage in the face-to-face meeting to the online, face-to-face meeting during the COVID-19 pandemic. However, the results of the calculation of the N-gain showed an increase in the moderate category. This happened because previously, students were given problems that required them to analyze these problems, then students were given a project to create a concept map based on their understanding and mastery of the concepts understood. Implementation of learning by providing problems can improve students' understanding of concepts (Fitriani et al., 2016). Herdianto et al. (2022) also found the results that the implementation of learning based on student activities could increase understanding of concepts.

Furthermore, to strengthen the results of the N-gain that has been obtained, students are given a questionnaire to measure their response to the implementation of online learning. The results of the response questionnaire show that 73.5% of students enjoy doing online learning, while 26.5% of students feel bored and less effective, but 84.6% like learning with this concept map. Then, the qualitative data were obtained by the researcher to strengthen the N-gain results. The students revealed some reasons via the distributed questionnaire by the researchers. They were such students who experienced learning online was not effective because of many hindrances. They were such that the applied learning sources were many, so the students were confused. Some learning sources were difficult to understand. The other problems dealt with hindrances due to the signal or lack of smartphone function capability. It was also strengthened by Rachmawati et al. (2020). They found that not all online learning could be accepted by students joyfully. However, it was different for some students. Some students felt that online learning made them think creatively, advance, and autonomously to do and achieve something they wanted. It was proven by Firman & Rahayu's statement (2020). They revealed that students who had basic online learning facilities had the flexibility to carry it. They were also encouraged to learn autonomously and motivated to learn more actively.

The qualitative data were obtained from the emerging conceptual understanding of pattern variety. The variety was the description of visualization results of the students' conceptual understanding. Yin et al. (2005) group the conceptual map into linear, circular, hub/spokes, tree, and network or net. The students could arrange the conceptual map based on the conceptual understanding development, their creativity, and the conceptual understanding condition of every individual. Canas et al. (2015) argue that an excellent conceptual map could develop excellent structured knowledge. Besides that, the conceptual mapping could strengthen the memory. This learning model became a learning model that made students remember and elicit creative and active ideas. It made the students learn anywhere by making attractive and understandable notes. Concept mapping experiences facilitate students to integrate new information into their knowledge framework, help them visualize their understanding more efficiently, and inform teachers about the structural dimensions of student understanding (Brandstädter et al., 2012; Conradty & Bogner, 2012; Ruiz-Primo et al., 2001; Schwendimann, 2015; Won et al. 2017). A conceptual map could also facilitate students to quickly and efficiently accomplish their tasks. Therefore, the conceptual map model was expected to improve the students' creativity in learning and learning outcomes (Ginting, 2017; Pardosi, 2017). Likewise, the results of research by Zulyani et al. (2014) show that there is a positive relationship between the making of students' concept maps and their learning outcomes.

The descriptive qualitative analysis results showed that the most frequently used conceptual map pattern by the students to improve their conceptual understanding based on science literacy with hub/spokes conceptual map pattern, 87.95%. The hub/spoke conceptual map is arranged similarly to a spider web. The results of interviews with 16 students showed that it was easier for them to make this pattern because it could present concepts ranging from general concepts to specific concepts. This concept map pattern only consists of one level (discussing one discipline) so that when a concept is missing it does not really affect the concept in general (Mahanal et al., 2016). This pattern is included in the category of simple patterns because it only connects one discipline without students being able to think in an integrated and holistic manner because it only focuses on certain disciplines/materials. These results are in line with the results of increasing students' conceptual understanding in the low category. Based on these results, it is known that students have not thought in a complex way by connecting concepts with one another. They only focus on one material and have difficulty thinking comprehensively. This is in accordance with previous research that 66.2% of students have a nominal level in achieving their scientific literacy skills (Fakhriyah et al., 2017), and based on the results of computational thinking analysis, it is known that students have only reached the stage of finding a solution pattern and have not been able to perform an algorithm, namely connecting concepts with various specific disciplines through a structured and systematic pattern (Fakhriyah et al., 2019).

It is drawn from the center into the sides. Kinchin (2000), Yin et al. (2005), and Pangestuti et al. (2017) state that in this model, the written concepts of the main concept were written and directed to the more specific concepts. The applied arrangement was top-to-down and side-to-side. Thus, the concepts would surround the main concept. Various theories about conceptual map variety should be recognized to differ the students' arranged conceptual map model possibilities. The conceptual map pattern variety distribution can be seen in Figure 3.

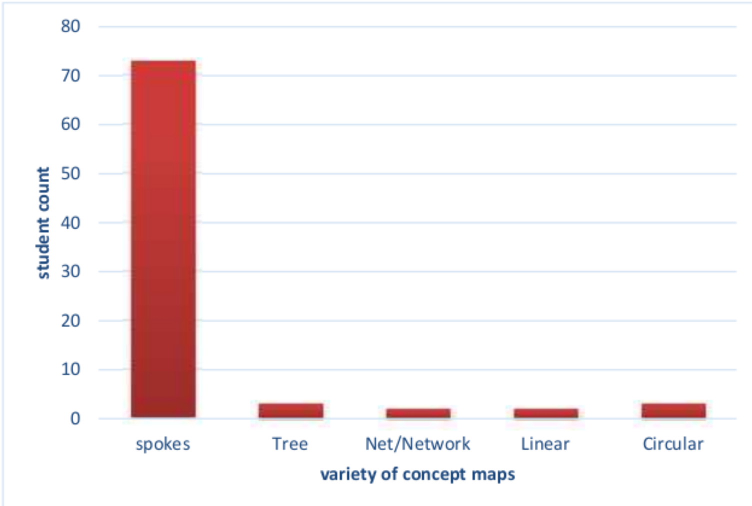

Figure 3. The Conceptual Mapping Pattern Variety Distribution

Asan (2007) states that conceptual map learning is useful for conceptual science learning. It is because the science concepts are inter-correlated and have many established concepts from other many concepts. Therefore, the conceptual map is useful for science class and learning material. Asan (2007) argues that a conceptual map facilitates students to understand a learning process. It also develops feedback and creates a meaningful scheme and knowledge base. The lecturers directed the students and followed the guidelines to arrange a conceptual map. Rusilowati & Sopyan (2011); Ramadhan et al. (2016); Rahayu et al. (2017) found five stages in arranging conceptual maps. They were 1) selecting reading material the global warming as the topic, 2) identifying the main ideas or principles covering the concept, and 3) determining the relevant concepts by identifying the secondary ideas or concepts to support the main idea about global warming as the topic, 4) ordering the concepts from the inclusive concept until the less inclusive concept (the main concept into the supporting or specific concepts), and 5) placing the main ideas in the center or the top parts of the map.

The hub/spoke conceptual map variety was the highest one. It showed that students realized the correct hierarchical structures for the topic. With this pattern, students could write the concepts from the general concepts into the specific concepts and the relevant and contextual ideas. According to Ruiz-Primo (2004), students' valid proposition of a conceptual map was based on the proposition possibility in the map. Its criteria should reflect the differences in conceptual understanding systematically. Canas et al. (2015) strengthened the finding by stating that an excellent conceptual map should contain proper graphic structures based on the hierarchical structures of the knowledge in a certain domain. It mostly leads to hierarchical structures in a conceptual map with the most common concept at the top part of the map while the more specific concepts at the lower parts of the map. Properly organized cognitive structures (required for meaningful learning) could lead to organized conceptual maps in the graphs.

The students' products of the arranged conceptual map were uploaded via their social media. They also provided captions of the concepts. This stage stimulated the students' creativity and invited them to use the social media platform meaningfully and adequately. Social media, Instagram, could be used by students to access other people's photographs and innovative video products (Rubiyati et al., 2018). Besides that, Scissons et al. (2015), Ghazali (2016), and Nugroho & Rahmawati (2020) stated that Instagram was an online application to share photographs, pictures, videos, and social networking. Here is Figure 4. One of the uploaded results of the students via their social media.

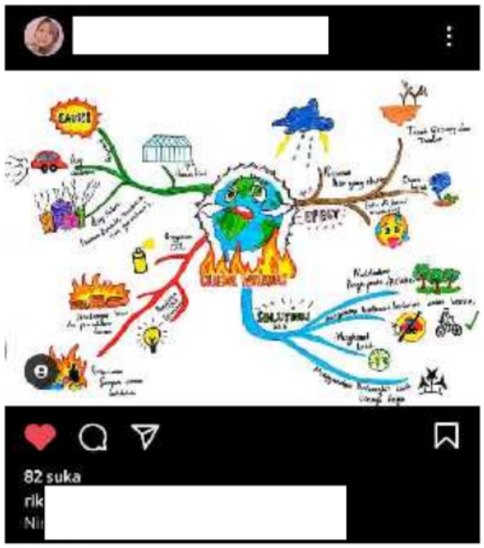

Figure 4. The uploaded student's conceptual map via social media, Instagram.

The conceptual map product should be uploaded via their social media. It was to guide them to be aware. One of them was by expressing and showing their identities via social media. Sakti & Yulianto (2018) found that every individual had the unlimited capability to express themselves. They also represented themselves via the creative products in determining their roles on social media, Instagram. Rubiyanti et al. (2018) revealed the influence of social media benefits, Instagram as a learning media, toward learning creativity. However, it should be used properly and wisely.

Conclusion

Based on the data analysis, it was concluded that there was an increase in student's conceptual understanding based on the N-Gain calculation of 0.53 with a moderate category, meaning that concept understanding increased through the application of science literacy-based concept map learning, even though the condition was 45% less effective when viewed from the category of interpretation effectiveness. N-gain, while the results of qualitative data analysis show a variety of concept map patterns that students often use to improve conceptual understanding using the hub/spokes concept map pattern as much as 87.9%. The concept map pattern that appears is a depiction of the visualization results of student concept understanding uploaded on Instagram social media. Similarly, the results of the questionnaire showed that 73.5% of students were bored with online learning, and 84.6% of students liked the concept of learning this conceptual mapping.

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