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INDONESIAN HIGH SCHOOL STUDENTS' PERCEPTION OF SCIENTIFIC EXPERIMENT USING NETWORK ANALYSIS: DIFFERENCES BETWEEN SCIENCE AND HUMANITIES GROUP

R. Q. Aini[1], Y. Sya'bandari[2], A. N. Rusmana[3], J. K. Lee[4], S. Shin[5], M. Ha*[6]

[1,2,3,6]Division of Science Education, Kangwon National University, Chuncheon, Republic of Korea
[4]Division of Science Education, Chonbuk National University, Jeonju, Republic of Korea
[5]Department of Biology Education, Chungbuk National University, Cheongju, Republic of Korea

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ABSTRACT

Understanding what students know about the scientific experiment is essential for their metacognition and their understanding of scientific inquiry. A total of 425 Indonesian high school students participated in this study. Using an open-ended question, this study examined science and humanities group students' perception of a scientific experiment by their narrative explanations. Language network analysis method was used to measure and visualize their perception by examining the relationship between each word of response and its patterns underlying the network. After the process of network analysis, nodes "prove," "observation," "problem," "hypothesis" only found in science students group while nodes "new" "object" "try" "test" found in humanities students group. These results also perceived that science students group considered scientific experiment as an inquiry process while humanities students were more likely into the discovery process. The results of this study could support how scientific experiment as a learning activity was taken differently in science and humanities class in high school.

Keywords: experiment, Semantic Network Analysis (SNA), scientific, students' perception

INTRODUCTION

Preparing students to be scientifically literate is the aim of education in several countries. For instance, knowing how knowledge justified in science is one of the goals in the K-12 science curriculum in the United States (National Research Council [NRC], (1996). Scientific literacy also has been the main focus on PISA assessment (Organisation for Economic Cooperation and Development [OECD], 2016) which aims for all the students across majors to use scientific knowledge in the real-world situation context. Generally, scientific literacy is intended for all students, regardless of whether the students will become a scientist or not, to use scientific concept and science knowledge for personal decision making. Based on the Indonesian Ministry of Education and Curriculum or K-2013 (2016), sciences is a systematic effort to create, build, and organize knowledge about natural phenomena and to solve problem. Therefore, science subject has an essential role in preparing students to be scientifically literate and their thinking process.

According to Indonesian 2013 curriculum (K-2013), science learning has been started in science subject since the 4th grade of elementary school level until middle school level in the 9th grade. In the high school level, Indonesian students choose their primary preferences, either science class, humanities (social science) class, or language and literature, class. Biology, chemistry, and physics are taught as independent subjects in a science major. However, non-science students can choose one or two preferable specialization science subjects during high school level. It indicates that science learning also taught in a non-science major in Indonesia based on a previous academic level (middle school) or preferable specialization science subjects during high school level. In particular, this science learning is expected to develop students' ability for scientific inquiry and apply it in the science classroom as well as real-world situation context.

*Correspondence Address
E-mail: msha@kangwon.ac.kr

In the context of the learning approach that suggested from Indonesian curriculum (K-2013), scientific approach in teaching and learning process is preferred. This approach encourages students to undergo the process of observation, to ask questions, collect information, associate the information, and communicate the results. It is applied from elementary to high school level for all subjects. In this case, teachers act as the facilitator to develop students' scientific skills and promote scientific literacy through a scientific approach.

People might assume that scientific skill is only preferred for science students as they conduct the scientific experiment in the classroom. However, scientific skill is also required for non-science majors for life skills. This is in line with Turiman et al. (2012) who argued that in preparing students to have the 21st-century skill for their competitiveness in the globalization era, science process skill as scientific skills needs to be fostered. It is very crucial to develop the scientific skill for students in all major. To prepare efficient and meaningful learning process, the teacher would be better to know how students perceive the scientific approach itself. Scientific experiment as a method for the scientific approach is also known as a process of justifying scientific knowledge (Lee et al., 2015). If students have a sufficient understanding of scientific epistemology and how science is conducted, they can have a better rational decision about scientific project and technology (Peters-Burton & Baynard, 2013; Liu et al., 2011). The term 'scientific experiment' is more familiar for students due to their science learning experiences in the classroom; therefore, this study intended to explore students' perception about the scientific experiment in science and humanities majors.

The experiment is an activity involving human intervention to understand about nature (Harré, 2002). The meaning of scientific experiment has been a debate for the various philosopher of science. Giurgea & Georgescu (2012) had explained the history of the experiment according to the philosophers Francis Bacon and René Descartes. Both philosophers revealed that methodologies using the experiment as the central method for the scientific method are to generate a causal explanation of a natural phenomenon. Later on, the "experimental method" was developed further in the nineteenth-century where the experiment intends to look for casual relations. According to Harré (2002), there are three different roles of experiment based on the history of science. First, inductivism, a scientist, produces laws and theories based on inductive as a result of the experiment. For instance, Newton used the inductivist theory by 'making a conclusion based on experiments and observation by induction. '

Bacon's result also proposed the inductivist theory, whose role of the experiment is to discover natural events and arrive at scientist's law and theories. Second, fallibilism. This view is introduced by K. R Popper where scientist should think that experiment is a test to examine the hypothesis rather than to confirm the hypothesis. The role of experiment result is to provide an unprovable assumption. Third, conventionalism. The role of the experiment is to illustrate a set of scientist idea and enable them to demonstrate their own theory. In this view, experiments do not provide data and facts for inducting laws or falsifying a hypothesis. For example, William Prout and Berzelious as biochemist scientists illustrated this views in the history of chemistry, where their experiments are not shown if laws were true or false, but their different prescriptions by empirical test showed distinct conventions for the words used.

Understanding scientific experiment for the students is necessary for metacognition in students' scientific inquiry and nature of science (Lee et al., 2015). Thus, according to Lehrer & Schauble (2015), the idea of the experiment from students is essential because it reflects their classroom activity and reasoning. The reasoning is an act of thinking; an inferring from statements during the process of knowledge acquisition (Evans, 2013; Zeineddin, &Abd El Khalick, 2010). By knowing students idea of the scientific experiment, the way the students think form one idea to another idea will be revealed. Furthermore, the students' perception of the scientific experiment will also unveil their process of generating knowledge.

According to DiSessa (2013), individuals' knowledge consists of "pieces," where their perception of a particular object has a network based on the connection with other concepts. These pieces of knowledge will form a mental model or structure of knowledge. In other words, students' perceptions of the scientific experiment are likely to form a connection between the various pieces of concept (Arma□an, 2017; Lee et al., 2015). Examining language and vocabulary used will report their standard of thinking system and understanding of the scientific experiment. Moreover, the language network analysis has been used in the field of education as a method for analyzing and visualizing students' perception structure (Bodin, 2012; Bruun & Brewe, 2013; Oshima et al., 2012; Schizas et al., 2013).

Semantic Network Analysis or SNA is one of the methods to capture students' perception from textual statements and present the connection between statements (Lee et al., 2015; Peters-Burton & Baynard, 2013). This network analysis works by processing network language and providing group information functioning as the direction of their interaction (Carolan, 2013). The implication of network analysis in education is to support teachers and education researcher for understanding students' cognitive structure as well as help investigate a latent aspect of the students' learning (Schizas et al., 2013). Therefore, this study used the language network method to identify the core concept vocabulary used in high school students toward scientific experiments and to understand contexts of experimental cognitive structures. The network analysis presents interconnectedness of students' ideas of a scientific experiment in nodes provided as this analysis' strength (Peters-Burton &Baynard, 2013). Multiple lines arise between connected nodes indicate the connection of more than one idea (Peters-Burton & Baynard, 2013). Another advantage of using the network analysis is the ability to know object position and how it is embedded within the network (Brewe et al., 2012; Van der Hulst, 2009).

The previous study by Park et al. (2014) examined Korean high school students and teachers' perception of the purpose of science learning using open-ended questionnaires and semantic network analysis method. Another study by Lee et al. (2015) had discovered Korean students' perception of the meaning of experiment in science and biology. Peters-Burton & Baynard (2013) also examined that scientist, science teacher, and students believe in the scientific enterprise using network analysis. The results showed that the network analysis method is useful for framing the group of people's view because of its function to visualize the connection of narrative statements. However, there is no research about Indonesian students' epistemological understanding of the scientific experiment yet.

It is also essential for humanities students to know how scientific research is conducted. Kayes (2010) argued that social science courses like sociology, anthropology, and social science could use the scientific method as a basic standard. Jackson & Cox (2013) also discussed the history of the experiment in social sciences and supported the use of the experimental design in social sciences. Furthermore, all students include in social sciences also need to have a deep understanding of science, not only recognize science vocabulary (Kayes, 2010). Therefore, this study intended to investigate how science and humanities group of students perceive "scientific experiment" that represents their process of generating knowledge. The research output also can expand scientific experiment epistemology in the Indonesian context. In other words, the research question of this study was: How are the differences between students in science and humanities group perceive the concept of scientific experiment?

METHODS

Data Collection

A total of 237 Indonesian high school students in science class group (134 first-year students, 61 second-year students, and 42 third-year students, comprising of 87 male and 150 female students) and 188 high school students in humanities class group (126 first-year students, 40 second-year students, and 22 third-year students, comprising of 54 male and 134 female students) involved in this study.

An open-ended question, *"please explain the definition of scientific experiment"* was used to investigate high school students' perception of a scientific experiment. The question was translated into Indonesian language (Bahasa) and

distributed using an online questionnaire form to high school students. To prepare the data analysis, the student answers were translated into English using google excel aided by Google Translate functions. To validate the answers, three researchers validated and checked the students' answers manually. Due to the system analysis, the meaningless answers meaning such as *"experiment", " I do not know",* and answers similar to internet source were excluded. A typical answer from the internet was seen from the same words and sentences. From a total of 883 students' participated in filling the online questionnaire, a total of 425 data were selected.

Data Analysis

In this study, the language network analysis method used the NetMiner 4 program. The NetMiner 4 is the software that can analyze both qualitatively and quantitatively the students' perception of a scientific experiment. The constructed-responses by the students were identified and generated into the visualization in the form of network map using the software. Qualitatively, this software explored the frequency and weight of word that can be determined by the researchers until the data and sufficient information resulted and formed the network maps. Quantitatively, the output of data analysis produced a statistical number of word including frequency, degree of centrality, and degree of betweenness centrality. Therefore, this software is appropriate for the objectives of this study.

After the data were translated and checked in English, the network analysis was performed. The structural characteristics of the network were computed based on the general matrix and calculated by words according to the frequency of occurrence at the same time in a single response (Lee & Ha, 2012). To have a sufficient result, the "frequency 3" was chosen, and only words that appeared more than 3 times in the text data were included in the network. Moreover, the "weight 5" was chosen, and the relation between each word was examined. The phrases which appeared more than 5 times were included in the network. Furthermore, the program also analyzed full-text units (document). Due to the repetition of questions which might affect the results, the phrase "*scientific experiment*" from the student responses was replaced into "*scientificexperiment*" and inputted as an exceptional list in the program. Thus, the word was not included in the data analysis. The analysis results were examined separately between science and humanities group class, but the same program setting was applied in both science class and humanities class. After the data texted imported into the program, the 2-mode network of SNA from the responses was analyzed. Afterward, the structure of students' recognition network was confirmed through the number of nodes from the words, the number of links, the network density, the degree of centrality, and the degree of betweenness centrality. Thus, the data were also analyzed based on the feature of the connection within the network.

RESULTS AND DISCUSSION

The research results presented the students' perception of scientific experiment based on the main words recognized in each group. Those words were chosen based on the frequency, in-degree centrality, and node betweenness. Afterward, the circle nodes that represent the words are visualized in the network maps. The formed network maps presented several groups of nodes based on its connection. As a result, this study discussed the group of an idea about scientific experiment found within the science and humanities students' responses. The discussion is based on the highlighted nodes/words appeared in each group.

Words Used Between Science and Humanities Students

The number of links that come into a node is called in-degree (Bruun&Brewe, 2013). In this study, in-degree centrality and betweenness centrality were used as indicators of the network status. Fifteen words that represent students' peace of knowledge about the scientific experiment are presented, and the degree of centrality between science and humanities students group were compared (Table 1).

The words "prove", "observation", "problem", "hypothesis" were found in the science group students. Meanwhile, in the humanities group students, the words "new", "object", "try", and "test" were found (Table 1). On the other hand, several in-degree centralities in the humanities group were smaller than the science group. Among these, the word frequently mentioned was "scientific" for both science and humanities group. The science students group participating in the study explained the meaning of "scientific" 64 times, while the humanities group explained the meaning of "scientific" 41 times. The next second most mentioned in the science group was "prove" while in humanities group was "research". The average centrality index of each words science students group than in was higher than humanities group students, which means that the number of links received from one word to another is higher. Based on the results, the science students group used a wider variety of words in a sentence to explain the meaning of scientific experiment than the humanities students group (Table 1).

Table 1. The Degree of Centrality Analysis between Science and Humanities Group

Science Group					Humanities Group				
No	Words	F	In-Degree Centrality	Node Betweenness Centrality	No	Words	F	In-Degree Centrality	Node Betweenness Centrality
1	scientific	64	1.818	0.364	1	scientific	41	1.036	0.123
2	prove	39	1.000	0.128	2	research	31	1.071	0.062
3	conduct	37	0.705	0.155	3	new	27	0.929	0.273
4	observation	34	1.091	0.092	4	find	26	1.321	0.160
5	science	31	0.705	0.157	5	object	19	0.857	0.050
6	theory	30	1.227	0.139	6	theory	19	0.964	0.205
7	find	29	0.432	0.064	7	science	18	0.393	0.040
8	activity	24	0.318	0.062	8	try	17	0.250	0.009
9	problem	22	0.409	0.054	9	conduct	14	0.107	0.000
10	research	21	0.432	0.000	10	know	14	0.107	0.000
11	series	18	0.750	0.000	11	activity	13	0.179	0.000
12	use	17	0.500	0.024	12	series	13	0.214	0.000
13	hypothesis	15	0.159	0.000	13	study	12	0.107	0.000
14	new	15	0.364	0.049	14	test	12	0.107	0.000
15	produce	15	0.636	0.039	15	thing	11	0.321	0.063

Information:
F = Frequency

Table 2 shows the density value of the overall connection between the participants. High or network density indicates the high coherency in the language used (Drieger, 2013). The humanities student group showed a more significant density (0.086) than science students group (0.075), which suggested that the response closely collaborated. However, the average degree of density in science students group was higher (1.644) than humanities student group (1.207) which indicated that in the whole network, the potential connection of science group was higher than the humanities group.

Table 2. Density

	Science	Humanities
Density: O(m)	0.075	0.086
Average Degree: O(m)	1.644	1.207

Science Students Group

Figure 1 shows the visualization of a scientific experiment by the connection of nodes and its interaction in science students group. The connection of the network was based on the connectivity degree centrality. The size of the node was determined based on in-degree centrality. Stand on the modularity, eight groups were found in science students group (Figure 1) with "scientific," "prove," "conduct" "observation" and "theory" become the center of their explanations. Five groups in science class were found connected each with the same nodes. Overall, in the science group, the highest degree was found in "scientific" "prove" "conduct" "observation" "science" words (Table 1). It indicated that those words played a crucial role in recognizing scientific experiment in science students. The most interesting part that the words "prove," "observation," "problem," and "hypothesis" only appeared in science students' network.

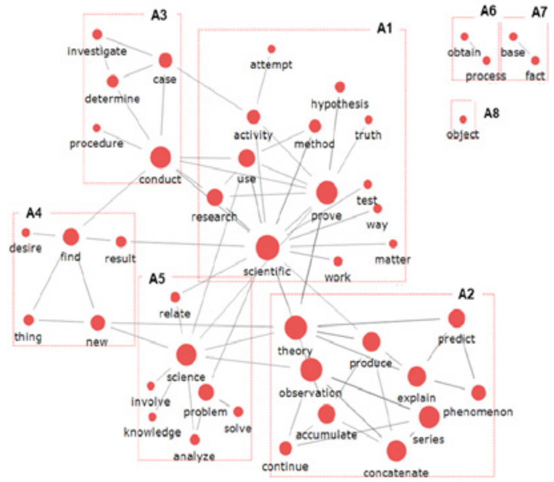

Figure 1. Nodes Network of Scientific Experiment in Science Students Group

A1. Scientific Experiment by Hypothesis Testing

In the first group (Figure 1, Group A1), the word "hypothesis" only appeared in science students' result. The experiment is a part of the scientific method where the hypothesis is an essential feature in this scientific investigation (NRC, 2002). The experiment aims to test the hypothesis (Gooding, 2012; Gyllenpalm &Wickman, 2011; Steffe & Thompson, 2000). By connecting the node of "hypothesis" with "prove" and "theory" (Figure 1, Group A1), it was shown in students' perceptions that hypothesis verification is one of the processes of a scientific experiment. The hypothesis is one of the variations to lead the scientific investigation (Wong & Hodson, 2009), which is the principal framework for scientific experiment. "Falsifiable" hypothesis, according to Karl Popper (Elgin, & Sober, 2017; Glass, 2010) and "testable" hypothesis is the requirement in scientific research, precisely in the experiment.

Deductive reasoning works for the testable phenomena by validating the hypothesis coming from the initial assumption (NRC, 2002). Another scientific principle is "pose significant questions" (Glass, 2010; NRC, 2002) and by using hypothesis testing, the questions will discover the phenomena and fill the knowledge gap (Glass, 2010; NRC, 2002). Thus, the important questions should be considered as "solid understanding of the relevant theoretical, methodological and empirical work that has come before" (NRC, 2002)". This is relevant to the results where the students expressed the words "activity", "method," "prove," "hypothesis." Even though the word "prove" is more likely into a process of verification than a falsification as a modern-day of hypothesis framework proposed by Popper. The Popper's framework of 'falsification" remains to have critics and debate because of the inconsistent with the substantive aim of experimental science (Glass, 2010).

A2. Scientific Method by Observation Driven

In the second group (Figure 1, Group A2), the "phenomenon" node appeared independently and connected with "predict" and "explain." Thus, based on this group, it was also found the node "observation" in which did not appear in the humanities student group (Table 2). The node "observation" was also connected with "theory." There was an overlapping idea whether the observation was included as a scientific experiment or not, where in this group, both terms aim to predict and explain phenomena. Moreover, according to Bogen (2009) and Malik (2017), to get scientific evidence and generate data to explain phenomena, the scientist uses observation and experiment as a scientific tool. Observation is used under the more natural condition to notice phenomena and get empirical evidence; also, has a role in theory testing (Bogen, 2009), which differs with an experiment under some modified conditions to test the hypothesis. According to scientific principles by NRC (2002), inferential reasoning also occurs in science based on "what is known and observed." It also showed that observation is one of the tools of scientific research for inference. Even though using a different type of reasoning to find out phenomena, both experiment and observation "provide an empirical base for theories is central to all theories of scientific method" (Gooding, 2012). Therefore, the research results indicated that science students could explain the role of observation as a scientific method.

A3. Experiment as an Inquiry Process

The third group (Figure 1, Group A3) is about "investigate" "procedure" "case" and "conduct." In other words, the perception of scientific experiments commonly presented in sciences students as an inquiry activity to investigate some case. As described previously, the results of designing experiment and observation are the main phase in the science lesson for generating inquiry skills (Palmer, 2009). According to Sadeh & Zion (2009), there are two types of Inquiry. First, *structured inquiry* where the teacher gives questions for students to investigate. Second, *open inquiry* where students determine the phenomena, build questions, hypothesizing as well as plan the experiment. In this *open inquiry*, the students determined the case by themselves. The *open inquiry* also demanded the students to investigate the topic questions and find a solution by their chosen method. This *open inquiry* method reflects the type of research and experimental work performed by scientists (Sadeh& Zion, 2009).

A4. Experiment as a Discovery Process

The experiment is a process, where these days "experiment" is a short of "controlled experiment" to understand the relationship between phenomena under some conditions (Gyllenpalm, &Wickman, 2011). The fourth group (Figure 1, group A4) is present the "find" "new" "thing" nodes. Another aim of the experiment, according to Gooding (2012), is to find new things. This finding new thing can also be called as the process of discovery. A success process of scientific inquiry is scientific discovery, which can be processes, things, or theories. In other words, according to the science student group result, this discovery process refers to the new invention as presented in the results.

A5. Experiment as Problem-Solving

The highlight point in the group is presenting the nodes "problem," "solve," "analyze," "knowledge". However, according to Bazerman (1988) and Lehrer & Schauble (2015), experiment is more than testing hypothesis but also reveals nature. The aims of the experiment are also for finding new things and problem-solving (Gooding, 2012). The previous study by Sandi-Urena et al. (2012) showed the improvement in students' problem-solving skills as the effect of a laboratory project in the implementation of the experiment. This implicates that science students group had aware of other objectives in the scientific experiment for problem-solving.

Humanities Student Group

There are seven groups found based on the modularity with "scientific", "research", "new", and "research" as the center of students' explanations. According to the results, humanities student group had a simpler network where three groups were connected with the node "new" while four groups are isolated (Figure 2). Noted that the based on the most frequent words (Table 1) produced, the words "new", "object", "try", and "test" only appeared in humanities student group.

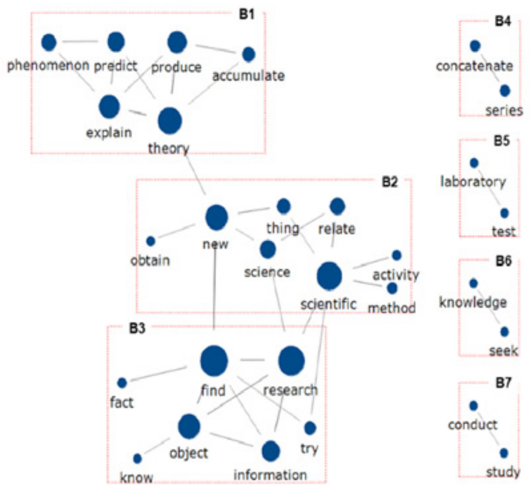

Figure 2. Nodes Network of Scientific Experiment in Humanities Student Group

B1: Experiment by Theory-Driven and Laboratory Task

The first group of humanities group showed the connection between the nodes "phenomenon", "predict", "explain", "theory", "accumulation", and "produce". Referring to Gooding (2012), experiment also reflects and comprises "an accumulation of understanding about what is going on". This group clearly showed that humanities students employed theory to produce, explain, and predict some phenomena. Another idea of humanities student group was isolated. For example, in Figure 2, group B5 had nodes "laboratory" and "test." A previous study by Gyllenpalm & Wickman (2011) suggested that rather than scientific inquiry, the term "experiment" also had the same meaning of "laboratory task" by teachers and students and more into the teaching method.

B2 and B3: Scientific Method by Discovery Process

Due to the isolated groups in the humanities student group, the discussion of two groups merged for the more meaningful discussion. The second and third group emphasized that humanities student group perception of the scientific experiment were more into the scientific method activity by the connecting nodes "find" and "new" as well as "scientific" and "research". The finding of new thing is to present the discovery activity, which as described before. This scientific discovery as a scientific method to generate new knowledge was also used by natural and experimental philosophy such as Bacon, Descartes, and Newton.

The Differences between Science and Humanities Group

Although humanities student group also used a scientific approach and experienced in science learning through middle school level or preferable specialization science subjects in high school, this study showed significant difference on how they perceived scientific experiment comparing with the science student group. Besides, the frequency of words was found in both groups, and the students' reasoning skills were also noticed based on several nodes provided. The specific perception of scientific experiment formed by science students consisted of both deductive reasoning and inductive reasoning, where they had nodes "observations" that connected with "theory" and the appearance of nodes "hypothesis" that connected with "prove". This is in line with Steffe & Thompson (2000) who argued that the aim of the teaching experiment method in the classroom is to encourage students' reasoning. Furthermore, science students' perception of scientific experiments was presented as an inquiry activity to investigate some case as well. In the current Indonesian curriculum (K-2013), science inquiry as direct experience cannot be outcast in science learning (Hairida, 2016). According to Longo (2011), an inquiry program is made for students to use the problem-solving process for learning through the process of scientific investigations. Based on the results, science student group had perceived scientific experiment as an inquiry process to promote the current curriculum while humanities student group had more novice ideas where the scientific experiment is more likely to a process of finding new things as a discovery process.

Given the result that science students have more opportunity to experiences scientific experiment in the classroom than humanities students, the idea of a scientific experiment in students also depends on how teacher take the experiment as a learning activity. Moreover, hours of science learning in the school and students' engagement with science also produced difference perception of a scientific experiment. Further research by examining students' attitude toward science for both science and non-science major can be a suggestion to understand the latent variable of their perception.

CONCLUSION

This study aimed to investigate Indonesian high school students' perception of the scientific experiment using qualitative network analysis method. In particular, this study examined the center words used around the concept of a scientific experiment in the students' cognitive structure between science and humanities group students. The concept of a scientific experiment perceived by science students group was more coherence, while humanities group of students was more isolated. As a result, the science students group understood scientific experiment as more into inquiry activity and centered on "scientific" "prove" "theory" and "science." With eight groups of the network, science student group had nodes "prove" "observation" "problem" "hypothesis" which did not appear in humanities students group. The results showed how the students perceived scientific experiment and revealed that science students group had both deductive-reasoning and inductive-reasoning as a process of scientific investigations. Moreover, science students also had a more sophisticated perception of scientific experiment as they included problem-solving and investigation in their explanations. In the case of humanities group, their perception of scientific experiment centered on nodes "scientific" "research" "new" and "find", where according to the network, only the node "new" was connected in three groups. Humanities students comprehended scientific experiment in more novices where the core of the experiment was finding new things. They did not discern the deeper meaning of scientific experiment as a scientific method as well as the nature of science.

In general, this result of the study can support how scientific experiment as learning activity is taken differently by science and humanities students in Indonesian high school. The students' perception can be different based on the gained knowledge and environmental support. This study also showed the students' engagement with the activity. Since humanities students can also take science subject, by comparing science and humanities students' perception about the scientific experiment, the teacher can prepare the effective teaching and learning method for both groups. Moreover, this could become evidence for developing experimental teaching method in the classroom to more emphasize scientific experiment so that the students have more scientific thinking through science.

This study showed that the network analysis method had expertly gathered the students' pieces of knowledge and the idea of a scientific experiment. Besides, this method is useful for assessment tools as well as the implication of teaching and learning. The results could be the evidence for developing teaching method which emphasize more on scientific experiment to encourage the students' scientific thinking.

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