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Research Artikel

ENHANCING ANALYTICAL THINKING SKILLS AND SCIENTIFIC ATTITUDES OF PROSPECTIVE SCIENCE TEACHER STUDENTS THROUGH PRE-PRACTICUM VIRTUAL SIMULATION

Naili Inayah[1*], Ahmad Lubab[2]
[1] Natural Science Education, Faculty of Education and Teaching Trainer, UIN Sunan Ampel, Surabaya, Indonesia
[2] Mathematic Education, Faculty of Education and Teaching Trainer, UIN Sunan Ampel, Surabaya, Indonesia
nailil.inayah@uinsby.ac.id [1]*

Abstract
Analytical thinking skills are important for science pre-service teachers to achieve the professional competence of science educators. The aim of national education mandates the formation of a complete human being through the development of character and attitudes in the learning process, including a scientific attitude. Data shows that students' analytical thinking skills are still below standard and scientific attitudes have not been sufficiently trained in learning. The purpose of this research is to describe the analytical thinking skills and scientific attitude of prospective science teacher students through pre-practicum virtual simulation. The research design was a post-test-only control group design with a sample of 55 prospective science teacher students. The data was taken using an analytical thinking ability test and a scientific attitude questionnaire. The instruments used are worksheets and web-based simulations. The experimental class conducted a pre-practicum virtual simulation before the field practicum. The results of the Wilcoxon test were <0,05 showing differences in students' analytical thinking skills through practicum and pre-practicum virtual simulation learning. The highest score of the analytical thinking skills indicator is 'organizing' namely 71,0 in the experimental class. Scientific attitude with the highest indicator is curiosity in the experiment and control class with percentages of 97% and 88% respectively. Overall, both analytical thinking skills and scientific attitude are enhanced through virtual simulation pre-practicum.

Keywords*: Analytical thinking, Practicums, Science prospective teachers, Virtual simulations.*

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*Corresponding author
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INTRODUCTION

Learning Natural Sciences develops thinking skills and curiosity, cares about nature and social structures, and brings concepts closest to real life to instill values in everyday life (Maison et al., 2022). The nature of science is a process such as high-level thinking skills, solving problems, and conducting investigations. Thus, habits of mind and investigations in learning science cannot be separated.

The competency of science educators in tertiary institutions requires mastery of high-level thinking skills such as analytical thinking which is practiced continuously in learning to form graduate professional competencies that are relevant to the needs of the times (Muhsin & Laksono, 2023; Hariadi et al., 2022). The ability to think analytically is one of the skills that is a quality demanded in most institutions providing employment opportunities, so it is necessary to prepare them to acquire this skill and use it effectively in the learning process (Phurikultong & Kantathanawat, 2022; Maison et al., 2022; KiRman & Kala, 2022).

Analytical thinking has a broad meaning according to the context of the applied field. In general, analytical thinking skills are the ability to collect, visualize, and analyze information to see the bigger picture or trends behind the facts. In other contexts, it is defined as the ability to take general information or an overview of a situation and deconstruct that information to identify its details, as well as systematic trends or links that unite them (Astriani et al., 2017). Analytical thinking refers to the ability to methodically break down complex problems into their parts, analyze patterns, and draw logical conclusions. This involves keen observation, critical judgment, and the capacity to think beyond the surface level. A strong analytical thinker can decipher complex details and look for connections between statements, concepts, descriptions, and other forms of knowledge. Analytical abilities increase with problem-solving and as curiosity develops, open-mindedness, and a willingness to explore different perspectives (Suyatman & Chusni; Maison et al., 2022).

Anderson and Krathwohl (2001) examine analytical thinking in the context of three basic skills: distinguishing, organizing, and dissecting. Distinguishing is differentiating what is important in a material or information obtained. Organizing is about understanding the relationship between parts and the whole. Dissecting requires identification or viewpoints that are not explicitly stated or analyzed in a particular material. Individuals who use these three basic skills effectively can evaluate information to solve a problem, choose the most effective solution, and see the relationship between the whole and the parts (Anderson & Krathwohl, 2001).

In a survey conducted by the World Economic Forum in the Future of Job Reports 2023, analytical thinking skills are the core skills most needed in the world of work. Creative and analytical thinking is the cognitive skills with the fastest growing demand until 2023 as much 73.2% and 71.6% respectively, followed by technological literacy and self-efficacy. The WEF further determined that the highest priority for skills training in the next 5 years from 2023 to 2027 is analytical thinking which is determined to account for an average of 10% of training initiatives. Based on the data of Learning Curve Pearson 2014, Indonesia is ranked 40th out of 40 countries at the fourth cognitive level (C4), thus analytical thinking skills still need to be improved (Yakub et al., 2021). Based on 2018 Program of International Students Assessment (PISA) data shows that Indonesian students' science abilities are in the category below Level 2 (OECD, 2023). The low level of analytical thinking skills is due to a lack of learning designed to stimulate and train analytical and problem-solving skills so that analytical thinking skills do not develop (Maison et al., 2022). They tend to remember or apply numbers to predetermined formulas.

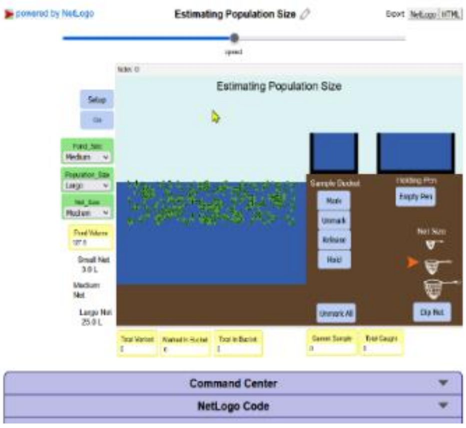
Analytical thinking skills also support and are related to critical thinking skills, scientific process skills, and scientific attitudes (Demir, 2022; Maison et al., 2022). Learning natural Science will be more meaningful if it is done through discovery, experimentation, or direct experience. Students are expected to be able to explore their abilities through the scientific process to discover facts from various natural phenomena through a series of scientific activities and media, built on a scientific attitude, to produce scientific products (Maharani et al., 2021). Developing a scientific attitude is one of the important results of science learning to form thinking characteristics that are relevant for a scientist. Scientific attitudes can be improved through various learning models and media (Rampean et al., 2021; Saputri et al., 2022). Students' scientific attitudes improve based on the results of studies in a virtual laboratory environment (Sharma & Gupta, 2023; Davis et al., 2022).

The material in the population estimation subtopic ecology course involves practicum, formulation, and data. The learning outcomes of the course are that students can master population concepts are skilled in solving problems related to population estimation, able to make appropriate decisions based on data and information analysis both independently and in groups. Simulation activities are one way of gaining an understanding of concepts by developing thinking skills based on real experience, changing abstract concepts into concrete forms, and enabling interaction, response, and communication so that they are easier to remember (Inayah & Masruroh, 2021); (Makiyah et al., 2019).

Simulation learning provides students with real-life experiences to absorb knowledge and practice skills in a realistic but simulated environment; helps improve non-technical work skills, such as effective communication, teamwork, collaboration, decision-making, and problem-solving, and improves knowledge retention (Hamdiyati et al., 2023). Real practicums provide real, authentic experiences, but often limitations in time, place and objects make their implementation less than optimal. Virtual experiences are a trend that can be adapted to be implemented in learning activities such as practicums or the application of certain models (Inayah et al., 2022). Learning with virtual simulations is easier to implement with supporting hardware and software devices. Virtual practicum can be carried out using computer simulations, containing instructions and procedures, data analysis, and several activities as in real practicum, but students do it in computer software (Widodo & Maria, 2016). However, the implementation of virtual simulations sometimes lacks relevance in life because they are not real and have limitations in terms of system errors that may occur. Simulation learning by combining the two can strengthen high-level thinking skills, especially analytical thinking (Widodo & Maria, 2016). Previous research generally only looks at the effects of one of the real practicums and virtual practicums. The use of virtual practicums was to substitute the real practicums. Thus, this research aims to describe students' analytical thinking abilities after being trained using virtual simulations pre-practicums in learning.

METHOD

The research design was a posttest-only control with the research population is prospective science teacher students at UIN Sunan Ampel Surabaya. The sample consisted of 55 students in the Ecology course, population estimation subtopic. Data was obtained from analytical thinking skills tests and scientific attitudes questionnaires. The 3 criteria for analytical thinking skills namely differentiating, organizing, and attributing (Supardi et al., 2019). Indicators of scientific attitudes are curiosity, responsibility, objectivity, open-mindedness, cooperation, perseverance, conscientiousness, and critical (Supardi et al., 2019**;** Isnaeni et al., 2021**;** Fadly, 2021)**.** The instruments used consist of analytical ability test sheets, scientific attitude questionnaires, simulation worksheets, and web-based simulation as shown in Figure 1.



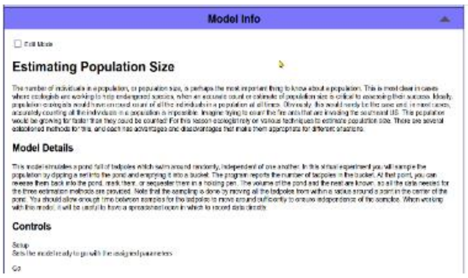


Figure 1. Web-based simulation

Data from the analytical ability test results were tested differently and analyzed using SPSS to see the differences in analytical thinking skills and scientific attitude between the group treated with field practicum and virtual simulation pre-practicum and the control group who only carried out field practicum. The questions prepared represent 3 indicators of analytical thinking skills. Analytical thinking skills and scientific attitude were trained through simulation worksheets consisting of work procedures, data columns from simulation results, and analytical questions related to data obtained from web-based simulations. Procedures carried out include; 1) preparation of research instruments; 2) implementation; 3) data analysis; and 4) conclusion. The procedures as shown in Figure 2.

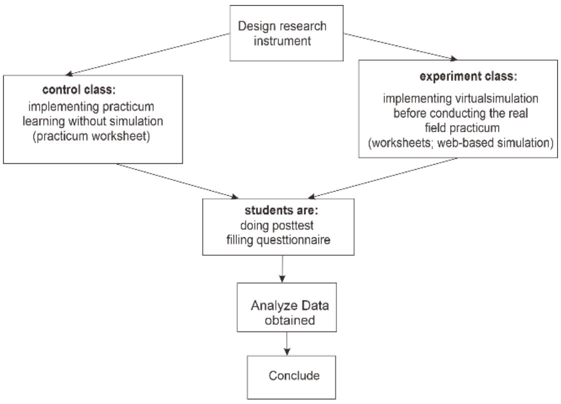


Figure 2. Research procedure

Based on the Figure 2., posttest data were analyzed using the Wilcoxon test since the sample is independent, sample size is small and not normally distributed to test whether the distributions of two groups are significantly different from each other (Cohen et al., 2011). Each indicator's score then will be averaged as the questionnaire.

RESULT AND DISCUSSION

a. Analytical Thinking Skills

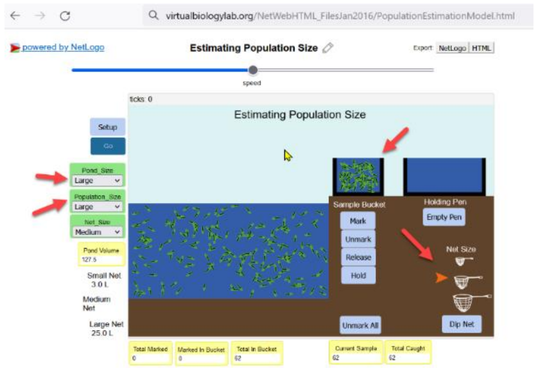
The extent to which students' analytical thinking skills can be measured by how lecture activities can train and enable students to gain these skills in their learning environment. For prospective science teacher students, this is important because they will later carry on the relay of designing such a learning environment for their students (Ennis, 1985; (KiRman & Kala, 2022). Besides, analytical skills need to be trained in learning so students do not have difficulties in interpreting non-routine problems or socio-scientific situations. Research shows that students have more difficulty solving conceptual problems based on interpretation than operational problems. Science is relevant to analytical thinking skills because it is close to real life. Analytical thinking is needed to understand mathematical calculation problems and equations in science to develop perspectives (Astriani et al., 2017; Yurt, E, 2022).

Table 1. Indicators and Sub-Indicators for Analytical Thinking Skills

No	Indicators	Sub indicators
1	*Differentiating*	a. Separating certain patterns b. Separate existing patterns
2	*Organizing*	a. Reasoning of applicable theories b. Application of theories to problems
3	*Associating*	a. Make a connection between what is given and what is requested b. Determine the main focus of the problem

(Hamdiyati et al., 2023)

The three indicators of analytical thinking skills are closely related to each other. In differentiating indicators, students are presented with a certain amount of information in the form of numbers. In this case, their ability to separate is honed, for example, which important data will be included in mathematical calculations. Apart from that, identifying and manipulating variables are also part of the ability to differentiate treatment and its consequences for a particular condition. In a virtual simulation using web-based simulation, students are given instructions for use and the opportunity to explore various features and manipulate the available variables such as net size, speed, pond size, and population size. The manipulations carried out are then recorded in a data table which will be compared with each other. The ability to differentiate is supported by the ability to understand and identify as well as giving questions in the form of comparisons and tables (Fadly, 2021; Wulandari et al., 2022). The exploration and manipulation of variables are shown in an example of student work in Figure 3.



Tabel 1.1 Hasil simulasi 1

	Ulangan 1	Ulangan 2	Ulangan 3	Ulangan 4	Ulangan 5
Tangkapan ke 1 (M)	35	29	32	31	37
Tangkapan ke 2 (n)	44	32	39	46	56
Jumlah ditandai ®	4	2	6	2	7
Ukuran populasi	385	464	624	713	296

Ulangi percobaan dengan langkah yang sama untuk;

Simulasi 2-Ukuran kolam sedang, populasi sedang, 1arring sedang

Tabel 2.1 Hasil simulasi 2

	Ulangan 1	Ulangan 2	Ulangan 3	Ulangan 4	Ulangan 5
Tangkapan ke 1 (M)	21	6	7	8	3
Tangkapan ke 2 (n)	25	7	11	14	12
Jumlah ditandai ®	2	1	2	2	1
Ukuran populasi	262,5	42	38,5	56	36

Figure 3. Analysis results using web-based simulation virtual biology lab

Most learning occurs when students have questions, which then guide their exploration of the simulation and lead their discoveries to certain answers. In virtual simulation learning, students have space to interact and engage directly in the simulations. When students engage in independent exploration they learn better (Inayah & Masruroh, 2021).

Organizing ability in questions is represented by applying a population estimation calculation formula to the data that has been collected/provided. In other words, organizing is an activity of combining and structuring empirical data into the theoretical formulation they obtain. In learning activities, organizing is also trained in the way they logically organize existing variables, repeating in practical simulation activities according to appropriate procedures to produce data (Anderson & Krathwohl, 2001; Muhsin & Laksono, 2023)

Associating is in the form of connecting one condition with another similar condition or connecting what is asked for with what is given. In this case, it requires a thorough understanding of the concept as well as good organizing skills to be able to associate well. The form of associating in a problem is, for example, looking for the relationship between one part and the whole, such as calculating a percentage. Apart from that, in learning, associating is trained by looking for connections between the conditions that have been provided with the new conditions they design in the simulation and conclusion. This process includes the operation of deconstruction to achieve a goal based on viewpoints, opinions, values and goals themselves (Astuti et al., 2021).

After being trained by virtual simulation for an experimental class, then the field practicum was conducted. Practicum activities describe the real conditions of the data collection process so that their relevance in everyday life is visible. Based on previous research, science virtual laboratory in science classroom encourage group learning and analytical thinking both in class and real life (Klentien & Wannasawade, 2016).

Results of the analytical thinking test were tested using a Wilcoxon test, shown in Table 2 as follows;

Table 2. Results of different tests in the control and experimental classes

		N	Mean Rank	Sum of Ranks
Analytical Thinking skills (control-experiment)	Negative Ranks	16[a]	13.56	217.00
	Positive Ranks	7[b]	8.43	59.00
	Ties	2[c]		
	Total	25		

Test Statistics

	Analytical thinking skills (control experiment)
Z	-2.405[b]
Asymp. Sig. (2-tailed)	.016

Table 2 shows the differences between the experiment and the control class-tested using the

Wilcoxon test. Based on Table 1, it can be concluded that the significance value is 0.016, which is smaller than 0.05. Thus, there are differences in analytical thinking skills in the control and experimental classes. This is because, through practicum and virtual simulation learning, students experience more in different conditions. A richer learning experience creates a better understanding. Research notes that students learn more when simulations are supplemented with other learning approaches rather than stand-alone instruction (Widodo & Maria, 2016; Davis et al., 2022). Students can solve science problems by connecting the observations that result in practicum with theoretical constructions to build a more comprehensive conceptual structure (Isnaeni et al., 2021); Saputra, 2022; (Yusup et al., 2022).

The analytical thinking indicators in this study were scored and averaged. The distribution scores of each analytical thinking skills indicator are shown in Figure 4.

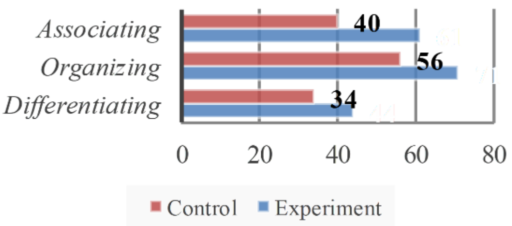


Figure 4. Distribution of scores per analytical thinking indicator

Based on Figure 4, the average score for ‘organizing’ in the experimental class reached the highest score of 0.71. The lowest score was differentiating at 44 in the experimental class and 34 in the control one. In general, differentiating indicators are categorized as easier compared to others. However, in the questions and exercises prepared, this indicator is in inductive form, meaning that students are asked to separate patterns after carrying out activities or calculations. This became a challenge that solving differentiating problems is practical, not theoretical (Suyatman & Chusni, 2022; Maison et al., 2022).

b. Scientific Attitude

Attributes of scientific attitude consist of curiosity, responsibility, objectivity, open-mindedness, cooperation, perseverance, conscientiousness, and being critical. The description of the sub-indicators is described in Table 3.

Table 3. Indicators and sub-indicators of scientific attitude

	Indikator	Sub Indicators
1	*Curiosity*	To be interested and enthusiastic in practicum and pre-practicum virtual simulation related to the given topic
2	*Responsibility*	Being responsible for completing assignments on time
3	*Objectivity*	Presenting data according to the facts and not copying from the other groups
4	*Open Mindedness*	a. Listen to another opinion b. Asking challenging questions related to the given topic
5	*Cooperation*	Being able to work in groups; active in group discussions and investigations
6	*Perseverance*	a. Having no despair in doing an experiment b. Having a habit of repeating the experiment c. Conducting practicum activities to completion
7	*Conscientious*	a. Working based on instruction systematically b. Making decisions based on the data collected c. Working carefully and paying attention to the empirical facts
8	*Being Critical*	a. Exploring information and paying attention to details b. Do not accept a conclusion without strong evidence

(Supardi et al., 2019**;** Isnaeni et al., 2021**;** Saputri et al., 2022)

The result supported by Saputra, (2022) and Kırılmazkaya & Dal, (2022) was that during the learning process using interactive media, students were trained to show a more objective, tolerant attitude and conclude actions according to facts. dare to ask questions and express opinions, be active in groups, solve problems, and record the observation results. All of these contribute to encouraging scientific attitudes.

Descriptive statistics of scientific attitude scales are shown in Table 4.

Table 4. Scientific Attitude Result

a. Experiment class

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Dev
Curiosity	30	3	4	3.88	.326
Responsibility	30	3	4	3.69	.471
Objectivity	30	3	4	3.69	.471
Open Mindedness	30	2	4	3.73	.533
Cooperation	30	3	4	3.65	.485
Perseverance	30	3	4	3.58	.504
Conscientious	30	3	4	3.69	.471
Being Critical	30	3	4	3.69	.471
Valid N (listwise)	30				

b. Control class

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Dev
Curiosity	25	3	4	3.54	.508
Responsibility	25	2	4	3.15	.613
Objectivity	25		4	3.42	.809
Open Mindedness	25	3	4	3.54	.508
Cooperation	25	2	4	3.50	.583
Perseverance	25	2	4	3.38	.637
Conscientious	25	3	4	3.58	.504
Being Critical	25	2	4	3.54	.647
Valid N (listwise)	25				

According to Table 4, the scientific attitude percentage of each indicator can be described in Figure 5.

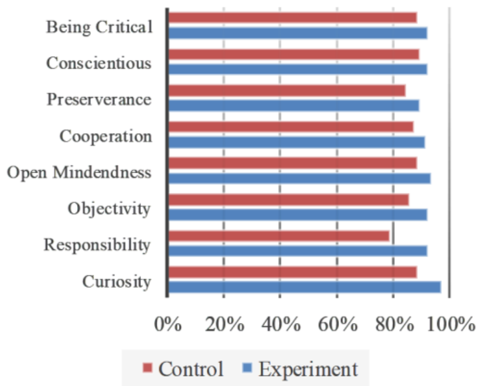


Figure 5. The percentage of each indicator from experiment and control classes

Based on Figure 5, for all indicators, the experiment class has a higher percentage. Since students have more experience with virtual simulation and practicum than those who only conduct one of them. Meanwhile, the Wilcoxon test result for the scientific attitude for both classes is shown in Table 5.

Table 5. Scientific Attitude Result for Wilcoxon Test

	Scientific Attitude (Ex-control)
Z	-6.279[b]
Asymp. Sig. (2-tailed)	,000

Based on Table 5, it can be concluded that the significance value is 0.000, which is smaller than 0.05. Thus, there are differences in scientific attitude in the control and experimental classes.

The curiosity indicator describes students' interest in carrying out practical activities and virtual simulations. This interest arises because virtual simulations provide features that can be selected according to the user's wishes and interactively provide feedback on these choices. For example, if the selected net size is too small and the selected population size is too large, the system provides feedback by indicating the discrepancy. Then the user will change his choice more rationally. In this way, during actual practicum, students know the consequences of their choices and can make the right decisions more effectively. The ‘curious’ indicator reached the highest score at 97% in the experiment class, while in the control classes only 88%. This is closely related to analytical thinking skills as the analytical abilities increase with problem-solving and as curiosity develops, open-mindedness, and a willingness to explore different perspectives (Suyatman & Chusni, 2022).

The responsibility indicator illustrates that virtual simulation can be accessed anytime and anywhere independently with the availability of an adequate device and internet connection without having to wait for face-to-face learning by the lecturer so it can be repeated as needed and prepare for the practicum better. In this way, assignments given can be fulfilled on time.

The ‘open-mindedness’ and ‘cooperation’ indicators describe the data collection process in the virtual simulation carried out in their group as a forum for group members' discussion. This learning was designed in pairs so that activeness in discussions and opinions is maximized and requires each group member to participate in scientific investigation activities with their group members. The richness of features in virtual simulations with the ease of variable manipulation (provided in worksheets) can stimulate challenging questions in-group members, such as 'what if', 'how can', etc. The scores of both in the experimental class are 93% and 91% for open-mindedness and cooperation respectively, while in the control class 88% of each.

The 'objectivity' indicator makes the data collection process based on actual data and is not the result of other groups. Having a virtual simulation before the actual practicum allows students to estimate the data they will get during the actual practicum, so they can overcome errors in the practicum and reduce misconceptions (Saputra, 2022).

The 'perseverance' Indicator describes in what way virtual simulation activities before the actual practicum can provide a habit of 'repeating' in the practicum. In this case, the worksheets facilitate a repetition column of at least 5 repetitions for each variation of variable manipulation. The existence of repetition in practicum shows a persistent attitude and having no despair easily, also not easily satisfied with the results unless repetition has been carried out and an outline of the data has been drawn. The repetition in the experiment group (89%) is higher because they have more saving time, tools, and effort in virtual simulation than in real practicum for doing repetition. So carrying out simulations in virtual space allows for many repetitions rather than real conditions. A scientific attitude can be developed by exploring and collaborating on activities to deeply understand natural phenomena (Ananda & Atmojo, 2022). An effective simulation debrief heightens the learner's self-awareness and self-efficacy for future situations (Peachey et al., 2021).

The 'conscientious' Indicator supported by worksheets that are prepared with sequential and systematic instructions, allows students to work systematically and procedurally in virtual simulation activities and actual practicums. There are guiding questions to lead them to the conclusion based on data that has been collected. 'Being critical' means activities designed with virtual simulations before practicum train students to make the right decisions based on the data obtained and pay attention to factors that may occur during the actual practicum.

CONCLUSION

Based on these results and discussion, it can be concluded that classes, where the virtual simulation is applied before practicum, have higher analytical thinking skills and scientific attitudes. The indicator of analytical thinking with the highest score is organizing, and scientific attitude with the highest indicator is 'curiosity' in the experiment class. This research strengthens previous studies in terms of how the combination of virtual simulation and real practicum can improve high-level thinking skills but differs in the type of thinking skills studied and the research design.

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