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Effectiveness of an Education Program with a Technological Pedagogical and Science Knowledge-Contextual Approach to Pre-Service Teachers' Understanding of the Nature of Science

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It is important to provide pre-service teachers and science teachers with an understanding of the Nature of Science (NoS) subject. The innovation of teacher education programs is important to produce natural science teachers, as demanded by the twenty-first century, and at the same time, to provide an adequate understanding of the NoS, namely with lecture programs of a Technological Pedagogical and Science Knowledge-Contextual (TPASK-C) based-approach. This study aimed to test the effectiveness of a lecture program with a TPASK-C based-approach in improving the understanding of the NoS in students. The research design followed a one-group pretest-posttest format. The subjects of this study were undergraduate students of Natural Sciences Education, using a purposive sampling technique. The instrument used was a NoS C+ comprehension questionnaire. The data was analysed descriptively with both effect size and inferential by using a paired t-test. The results showed that the lecture program with a TPASK-C based-approach had a strong effect on the NoS understanding, and there was a significant difference in students' NoS understanding before and after the implementation of the TPASK-C lecture program. This was indicated by the effect size value of greater than one, and the results of the paired t-test, with a significance value of less than 0.05. These results indicate that the TPASK-C approach program is effective in developing a NoS understanding.

Key words: *Nature of science, Education program, TPASK-C approach.*

Introduction

The education system requires an improvement of its quality, so that it can adjust to the rapid changes caused by globalisation. The key to success in improving the quality of education depends on the quality of teachers (Agbonkpolo et al., 2020). The professionalism of teachers becomes an essential requirement to realise quality education, namely teachers who have the capacity and responsibility in planning future education (Haseena & Mohammed, 2015; Roofe & Cook, 2017). Education can succeed if there is support in the form of teacher professionalism.

Qualified teachers are required to have four types of competencies, namely: professional competence, personal competence, pedagogical competence, and social competence, as stated in the Law of the Republic of Indonesia number 14 of 2005, concerning Teachers and Lecturers. The National Science Teacher Association (2003) sets ten standards for science teacher preparation, including content standards, nature of science, inquiry, science issues, general skills of teaching, curriculum, science in the community, assessment, safety and welfare, and professional growth. Furthermore, the National Science Teacher Association (NSTA) updated the standards for the preparation of natural science teachers, which were released in 2012, to include six standards that reflect the competence of natural science teachers, especially science pre-service teachers (Mokshein et al., 2015). Improving the quality of teachers is crucial in education and is still a challenge in Indonesia.

Based on the standards regarding the preparation of science teachers by the NSTA, it is stated that the primary role of teachers in science education reform focusses on the conception of the Nature of Science (NoS) subject and classroom practice (Lederman, 2007). Cobern and Loving (1998: 73) argue that the NoS is an important subject, even though it is difficult to teach meaningfully and effectively to pre-service teachers. However, the research results of Ratnawati et al. (2017) showed that the NoS of chemistry education students in the third year was quite sufficient (60.73 per cent). The results of this study are in line with the results of Yalcinoglu and Anagul's (2012) research, which showed that the NoS view of pre-service elementary school teaching students in Turkey is still wrong, as well as the research of Abd-El-Khalick and Lederman (2000), which found that the incorrect NoS view is owned by the student teacher, undergraduate, and graduate candidates. Abd-El-Khalick and BoBouJaoude's (1997) research results show that science teachers have an incorrect understanding of several of the NoS views, and do not show sufficient knowledge and understanding related to the structure, function, and development of scientific disciplines. These results are in line with the research of Widowati et al. (2017), which showed that in the understanding of science teachers in the Yogyakarta City Junior High School, there are still several aspects of the NoS that remain incorrect. For example, hypotheses are always a theory or law, and science is obtained only through experimental activities. The understanding of NoS junior high school students in the City of Yogyakarta is good for the aspect of attitude, but shows a lack of understanding of the aspects of science products, and a very poor understanding of the aspects of the process. This is in line with the results of several studies, where the understanding of science teacher's NoS is inadequate and wrong (AbdEl-Khalick & BouJaoude, 1997; Lederman, 1992; Buarapan, 2013). Of course, this condition is dangerous because teachers must have an understanding of the NoS to communicate the understanding of the NoS to students (Lederman, 1992). Without a good understanding of the NoS, then naturally, there will be inefficiency and ineffectiveness in learning science (Abd-El-Khalick & Lederman, 2000). As revealed by Widowati et al. (2018), most students of the Yogyakarta City Junior High School have an understanding of NoS that remains very lacking for the aspect of the process, less so for the product aspect, and is good for the attitude aspect. These facts confirm that understanding the NoS is an issue in international education. This research implies that the development of a NoS understanding is important for pre-service teachers.

Fensham (2016) states that there are no examples of serious education in understanding the NoS, even in professional development programs for science teachers. Studying the understanding of the NoS teacher candidates and early teachers is important, although it provides a picture that may not yet highlight how and why teachers apply the NoS (Krajewski & Schwartz, 2014). Therefore, it is important to study the development of a NoS understanding through an explicit and reflective learning approach, so that the NoS understanding of teacher candidates can be optimised.

The innovation of teacher education programs is important to produce science teachers, as demanded by the twenty-first century. Pre-service teacher education programs have a responsibility to prepare future teachers to teach students who are now characterised by ongoing technological changes. Teacher education programs in Indonesia have not been designed based on a specific framework for teacher professional development. This is not synchronous with the National Science Education Standards report (Peterson & Treagust, 1995), which stated that in learning to teach science, teachers need a component of analysis about Pedagogical Content Knowledge (PCK) which is called science, learning, and teaching. Several tertiary educational institutions implicitly use Shulman's PCK. Of course, this is inadequate in building the professional abilities of future teachers to use technology integration to improve learning and teaching in the twenty-first century. Therefore, there needs to be a shift towards the more contemporary conceptualisation of the Technological Pedagogical Content Knowledge, commonly called TPCK, and now known as TPACK.

As an approach, TPACK is developed technology integration in learning where teachers teach with technology, design teacher education curricula, and design the use of technology in the classroom. Smetana and Bell (2012) suggested that TPACK offers a framework for understanding how teachers' flexible knowledge of content, pedagogy, and technology interacts and enables teachers to apply effective instructional practices during technology integration in teaching. This is achieved by the standard process for teacher education, also stated in law number 55 of 2017, Article 9, Section 3, Paragraph 4, noting that learning in teacher education applies the principles of: (a) lecturers as models, act as role models for pre-service teacher students; and (b) pre-service educator students gain authentic experience via direct learning as early as possible in real situations in the education unit.

The TPACK approach for teachers and science pre-service teachers is important to combine with the NoS and contextual matters, so that the TPACK ability obtained by teachers and science pre-service teachers is specific for teaching science, as it is essential. The combination approach between TPACK, NoS approaches, and contextual matters is hereinafter referred to as the Technological Pedagogical and Science Knowledge-Contextual approach (TPASK-C). The TPASK-C approach is unique because it has the specific subject matter in the form of science and is oriented towards learning science by raising issues and phenomena in the surrounding environment, family, school, and community. Most of the research conducted by the TPACK approach emphasises more on the technological elements, so the development of the TPACK-C lecture program, in this case, makes technology a supporter (not the main aspect) and is combined with the NoS, as well as a contextual approach. This makes the TPASK-C an innovation because it has never been developed before. The lecture is designed to start from the exploration of contextuality that is presented in nature (as an object of natural science). Subsequently, the science pre-service teacher (undergraduate student of Natural Science Education) is facilitated to be able to raise these components to become a science learning scenario based on student active learning, and at the same time, integrate the content of the NoS.

Based on the background above, it is important to examine the effectiveness of lecture programs with the TPASK-C approach upon understanding the NoS. It aims to determine the effect of lecture programs upon the understanding of NoS in science pre-service teachers.

Method of Research

The study was conducted with a one-group pretest-posttest design, referring to Ary (1982), as in Table 1.

Table 1: Research Design

Pretest	Treatment	*Posttest*
Y_1	X	Y_2

The test subjects in this study were students of the Natural Sciences Study Program. The subjects were selected by purposive sampling, with the criteria of S1 undergraduate students majoring in Natural Sciences taking courses that were used as role models for the TPASK-C lecture program. The trials were conducted at the Yogyakarta State University (UNY), and Sarjanawiyata Tamansiswa University (UST) Yogyakarta. The instrument, used in the form of the NoS questionnaire, was developed based on the work of Lederman et al. (2002) with the VNoS-C form and improved by Buarapan (2013: 21) into VNoS-C +, which is the NoS questionnaire for pre-service teachers with aspects of the NoS: (1) tentativeness; (2) basic empirically; (3) subjectivity; (4) creativity; (5) embedded social and cultural; (6) observation and interpretation; and (7) theory and law. The sum of the item was ten items.

The questionnaire was embodied in the form of a series of statements. The scoring of each statement comes from the answers of students who scored '1' to '4', adjusted to the scoring rubric. The score was processed into a maximum standard value of 100. Furthermore, the values were analysed descriptively in terms of the mean and standard of deviation, and then the effect size was calculated to determine the effectiveness of the lecture program approaching the TPASK-C upon the understanding of the NoS, with the following formula:

$$\text{Effect size} = \frac{mean\ posttest - mean\ pretest}{standard\ deviation}$$

The effect size results were then interpreted, with the provisions as shown in the Table 2.

Table 2: The Interpretation of the Effect Size

Size	**Interpretation**
0–0.20	Low
0.21–0.50	Modest
0.51–1.00	Moderate
>1.00	Strong

Results and Discussion

The knowledge of subject matter is considered a prerequisite for teaching (Faisal, 2014). It is also in line with the statements of Kleickmann et al. (2012), that content knowledge (CK) is a key component of teacher competence, which affects student progress. As a science teacher, an understanding of the NoS matching is vital, so that science teachers can have superior competence. In this case, the effort being made is to use a lecture program with a TPASK-C approach.

The TPASK-C approach is an approach that has a philosophical concept of critical pedagogy (humanistic education) and its learning integrates the Nature of Science (NoS) in TPACK, which is more specific to science and makes technology as a support for learning. At the same time, it is combined with contextual learning by paying attention to how to present the science content (Widowati et al., 2020). The contextual learning in question, is learning that is based on the thought that meaning arises from the relationship between the content and context by involving students in important activities that help link academic learning with real-life contexts (Johnson, 2011). Contextual learning is defined by Hudson and Whisler (2006) as a way to introduce content using a variety of active learning techniques that are designed to help students connect what they already know to what they are expected to learn, and to build new knowledge from this analysis and synthesis.

As an innovative lecture program, the TPASK-C approach lecture program must be tested for its effectiveness upon an understanding of the NoS. The test results are based on the descriptive questionnaire data, as shown in Table 3.

Table 3: Recapitulation of the NoS Understanding Questionnaire Results

Aspect	**A (N=25)**	**B (N=34)**
Mean Pretest	21.73	35.71
Mean Posttest	54.33	51.71
Effect size	1.48	1.08

Table 3 shows that the mean posttest is higher than the average pretest value of understanding the NoS. The effect sizes obtained in both classes reached more than one, which means that there is a strong influence of the TPASK-C approach lecture program upon and understanding of the NoS.

The data from the questionnaire results were also tested in inferential statistics. To determine the tests performed, parametric or non-parametric tests are conducted prerequisite tests in the form of normality tests and homogeneity tests. Based on the results of the normality test results, as shown in Table 4, the data understanding of the NoS is normally distributed with a significance value of more than 0.05.

Table 4: NoS Understanding Data Normality Test Results

Aspect	**Kolmogorov-Smirnov Z**	**sig.K-S value (2-tailed)**	**Interpretation**
Pretest A	1.050	0.220	Normally Distributed
Posttest A	0.572	0.900	Normally Distributed
Pretest B	0.553	0.920	Normally Distributed
Posttest B	0.878	0.424	Normally Distributed

The significance value of the homogeneity test which was used as a benchmark is the Lavene significance value, by analysing the pretest data. The homogeneity test results of the NoS understanding data show a significance value of 0.055 (>0.05), so H_0 is accepted. This means the the NoS understanding data came from populations that have a homogeneous variance. Furthermore, the NoS understanding data was tested parametrically using the paired t-test.

Based on the paired t-test results, the obtained significance value p (2-tailed) 0.00 <0.05, both in class A and class B, so H_0 is accepted. The paired t-test results are shown in Table 5.

Table 5: t-paired Test Results Understanding NoS

Pair	t	df	*Sig.* (*2-tailed*)
Pretest-Posttest A	-8.74	24	0.000
Pretest-Posttest B	-9.53	33	0.000

Table 5 shows that there is a significant difference in the understanding of the NoS before and after the lecture program approaching the TPASK-C, with a significant value of less than 0.05. The results reviewed above show that the lecture program approaching the TPASK-C was effective in developing students' NoS understanding. This may be because the lecture program approaching the TPASK-C provides an opportunity for students to be actively involved in learning science through a natural exploration to formulate a scientific problem, to map concepts by making mind maps and concept maps, designing scientific methods to solve scientific problems, and designing how to teach science using the NoS content. This makes the TPASK-C lecture program close to one of the NoS content development strategies, and its teaching is a vital component for teachers. The variety of methods and techniques in the lecture program approaching the TPASK-C in the form of projects, analogies, discussions, nature explorations, and observations, can also encourage students to research like scientists (Novianti & Suparman, 2019).

The lecture program which approaches the TPASK-C can be recommended for application in lectures for science teacher candidates. Moreover, as Mercado, Macayana and Urbiztondo (2015: 101) state, the lecture method of pre-service teachers must develop an understanding of the NoS. For science teachers to effectively present NoS teaching, teachers must have an understanding of the NoS themselves, and knowledge of pedagogical content about the NoS teaching. Buarapan (2013: 17) also states that to help students have an adequate understanding of the NoS, the science teacher must first have an adequate understanding of the NoS. The teachers' understanding of the NoS will be more adequate if it has been prepared whilst they are in the pre-service teacher phase.

Conclusion

Based on the results and discussion above, it can be concluded that the lecture program which approaches the TPASK-C is effective in developing students' NoS understanding. This is indicated by the effect size value of more than one, and paired t-test results with a significance value of greater than 0.05. The lecture program which utilises a TPASK-C approach, provides an opportunity for students to be actively involved in learning science through a natural exploration to formulate a scientific problem, to map concepts by making mind maps and concept maps, designing scientific methods to solve scientific problems, and designing how to teach science with NoS content. This makes the TPASK-C lecture program close to one of the NoS content development strategies, and its teaching is a vital element for teachers.

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