The Innovative Framework for Developing Science Teacher Education: NOS Within TPACK

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Abstract. Skill in using effective technology in learning has become an important skill for science teachers and an important topic in current research. The integration of technology in education grew rapidly in the 21st century, and influenced the shift in pedagogical content knowledge, and was known as TPACK. Equally important in the science, the NOS payload must also be integrated in TPACK for the science teacher's education so that the fundamental principles of science learning are not forgotten and the science learning that is held as characteristic of science. The innovation of integrating NOS loads in TPACK, hereinafter referred to as NOS-loaded TPACK is essential for the development of the quality of science teacher education.

Keywords: Innovative; Teacher education; NOS; TPACK.

1. Introduction

A major challenge for LPTKs to realize the profile of graduates of professional candidates (strata 1), among them must prepare curriculum as a guideline for the implementation of education that must be able to guarantee the achievement of graduate’s competency according to Indonesian National Qualifications Framework level 6. However, LPTK quality is still a problem alone in Indonesia. The Institute of Accreditation of Higher Education [1] provided data that from 422 LPTKs in Indonesia still experience quality disparity, there are still about 1,600 study programs still accredited C from approximately 3,300 LPTK accredited products, still over graduate supply of Academic Education / Bachelor of Education, and most LPTKs do not have a laboratory school and a partnership system with schools.

The result of teacher competence test in 2015 to 2,430,427 teachers shows that the national average has not reached the target, that is 53.05 from the target 55. Professional proficiency score 54.77; while the average score of pedagogic competence is 48.94. The lowest average UKG score in one province outside Java only reached 41.96. For example, the DI Yogyakarta area, data on the number of teachers who attended the science-science subject of SMG in 357 schools in DI Yogyakarta Province, with an average score of 62.16 [1]. Teacher Competency Test Results (UKG) can be used as a reflection of the quality of Indonesian teachers, which still needs to be improved.

Pre-service teacher education programs have the responsibility to prepare future teachers who tend to teach their students in a world characterized by ongoing technological change. Efforts to improve the quality should be done, among others, by preparing professional teachers through the provision of teacher-producing education at the Institute of Education of Teaching Personnel (LPTK). Teacher competence is, of course, related to LPTK development activity in developing teacher competency of
the teacher candidate. Efforts that need to be done in the form of a series of development activities in LPTK for the development of pedagogical competence for prospective teachers.

Most teacher education programs in Indonesia have been designed using Shulman’s Pedagogical Content Knowledge (PCK). Surely this is not sufficient in building the professional ability of future teachers to use technology integration to improve learning and teaching in the 21st century. It is necessary to shift the reference to a more contemporary conceptualization of Technological Pedagogical Content Knowledge called TPCK, now known as TPACK. Apparently, teacher preparation using technology is key in most education improvement and education reform plans.

Currently, there has not been much of a theoretical foundation and conceptual framework as information and educational research guides in learning that highlight technology as a major weakness. Therefore, it still needs a literature review that discusses TPACK. Moreover, TPACK framework has an important role in the current rethinking of teacher education and the practice of using technology in learning. Moreover, the current life where technological advances more rapidly, teaching with technology to be something that should be done by teachers and is believed to be learning Net Generation.

Not less an important thing for prospective teachers of science is also ideal if it has a good understanding of Nature of Science (NOS). Why is that? This is because NOS deals with whether the science is and how the science works and also the NOS plays an important role in the development of scientific literacy. However, as Cobern & Loving [2] suggests that "The nature of science is important though difficult subject to teach meaningfully and effectively to pre-service teachers". Mercado, et al suggests that the pre-service teacher method should advance the understanding of NOS [3]. It is given that if science teachers can effectively present NOS teaching, they must have an understanding of their own NOS and pedagogical content knowledge about NOS teaching.

Based on the above reviews, it is important to discuss and be initiated about the innovation framework model for the development of teacher education for prospective teachers of science in this digital age. In this case the idea of innovation in the form of NOS within TPACK framework. Innovation is expected to be an idea for improving the quality of science teacher education in the form of efforts to prepare and create professional science teachers to face the Z generation, which is the designation for the generation of technology literate.

The rest of this paper is organized as follow: Section 2 is about literature review. Section 3 describes the proposed research method. Section 4 presents the obtained results and following by discussion. Finally, Section 5 concludes this work.

2. Related Work
This section presents the literature review.

2.1 What are the Reasons for Developing Technology Integration in Teacher Skills?

Knowledge about integrate technology in learning is an important thing for preparing prospective teachers to be more qualified to learn about students in the digital age. It is no longer appropriate if the level of teacher use of technology is low to meet the needs of 21st-century students, who are surrounded by a variety of digital media. Using adequate technology to support learning in the best way is recommended by Lawless & Pellegrino in [4]. There are several directives that emphasize technology as a key component to the change of educational system which is the main reason for educators and education stakeholders to believe that growth relates and implies technology and technology-based school innovation [5], among others:(a) Technology can showcase some of the key functions in the change process, including opening up new opportunities that enhance learning-especially with regard to the ability to adapt learning needs to the needs of learners, which is strongly supported by science; (b) Skills for adult life include technology literacy; (c) Technology is an integral part of accessing high-level competencies often referred to as 21st Century Skills. In addition to this, in the digital age, students not only access, manage, create and share knowledge in very different ways as their teachers often do, but also have extreme new expectations about what a quality learning experience should be [6].
Developing the use of technology in learning is essential for improving education. As Kozma argues that students always play an active role in learning by using technology to seek and gather information and publish and share their findings [7]. They are now more involved and can make a better connection between their previous learning experience and the new concepts or principles being taught. Smetana & Bell emphasizes the role of knowledgeable and capable teachers demonstrating the need to consider educational technology and the context of specific content and pedagogical areas [8]. Teachers have a challenge to mastering the teacher's knowledge by posing the concept of knowledge of pedagogical knowledge technology [9].

To achieve the kind of technology usage needed for 21st-century teaching and learning [10; 11], the knowledge needed to help teachers understand how to use technology to support meaningful learning, that learning enables students to construct and link knowledge one with other knowledge, applicable to real situations. Although "technology can make teachers faster or easier to teach the same things as routines, but technology integration allows for the adoption of new and better-span approaches to learning and/or changing the content or the context of learning, teaching, and assessment" [4]. The use of technology to support meaningful learning is what most teachers perceive to be the most challenging. This is possible because teachers need the most changes, including paradigm shift thinking that technology is difficult, transforming learning strategies, and how to represent content so that students can understand.

Lessons or lectures during initial teacher education differ from teaching and learning while teaching [12], and further differences can be made between learning and becoming teachers [13]. Beck & Kosnick state that when discussing the role of associate or teacher supervision in early Teacher Education, identified two broad learning concepts to teach [14]. The First, the construct of teaching and learning is similar to the internship, where students are socialized into the daily activities and the reality of the practitioners, while the second, which they label critical interventionists, focuses on encouraging critical students to question and reflect, focusing on encouraging critical students to question and reflect on day-to-day practices and beliefs. A teacher's knowledge gained while meeting the demands of their daily work is often referred to as the "Knowledge of the craft" [15; 16]. In the ideal world, prospective students will appreciate the significance of "craft knowledge" before graduation.

2.2 What is TPACK?

According to [8], 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 integration technology in teaching. Technological Pedagogical Content Knowledge abbreviated as TPACK (previously abbreviated as TPCK) is a necessary knowledge to integrate technology in learning. TPACK is important in preparing prospective teachers to be more qualified to learn about students in the digital age. Graham et al. [17] defines: “TPACK as the knowledge that teachers possess if they are able to know: a) how technological tools transform their pedagogical strategies and content representation for teaching particular topics, and b) how technological tools and representation impact a student’s understanding of these topics”.

It means TPACK as the knowledge that teachers need to be able to know about: (a) how technology tools transform teaching strategies and represent content for learning topics; (b) how technology tools and representations impact students' understanding of the topics being studied.

Hsu defines "TPACK is a knowledge construct that transforms with respect to technological affordances and available technological resources" [18]. TPACK is a very good type of specialized knowledge that supports the integration of content-based technologies. It has been characterized as a few intersections of teacher knowledge about curriculum content, common pedagogy, technology, and contextual influences while learning [19] and only begun to be explored in depth teacher professional learning. Based on these definitions, it can be understood that TPACK is knowledge of technology integration in learning.
2.3 What are TPACK Components?

TPACK has seven components as the basis for what might be said to be a classical representation of technology interaction, pedagogy, and content, consisting of (1) Technological Knowledge (TK) is knowledge of how to operate a digital device and use software; (2) Pedagogical Knowledge (PK) is the knowledge of theories and methods of learning and teaching; (3) Content Knowledge (CK) is knowledge of the subject matter; (4) Technological Pedagogical Knowledge (TPK) is the knowledge of how technology can be used appropriately for teaching and learning, (5) Technological Content Knowledge (TCK) is the knowledge of how technology can represent the subject matter; (6) Pedagogical Content Knowledge (PCK) is the Knowledge of how appropriate teaching methods can be applied to teach a particular discipline; and (7) Technological Pedagogical Content Knowledge (TPACK) is the knowledge of how technology and pedagogy can be used appropriately for effective teaching and learning in specific disciplines [9]. The TPACK framework is depicted in Figure 1 as follows.

![Figure 1. TPACK Framework and Knowledge Components](image)

2.4 How to Develop TPACK?

The development of technology integration approaches in appropriate pedagogical experiences is still limited so that the creation of new knowledge base based on different teaching components becomes difficult for prospective teachers as it requires an in-depth understanding of the knowledge and interpretation of the core context of its teaching and dynamics. Developing pedagogical content knowledge (PCK) is a major factor in overall technology integration. Teachers should make it a priority to acquire a PCK before integrating technology. In improving teacher education, PCK development must be supported by actual teaching experience [20].

Learning in this decade has been increasingly understood as a constructive process. Such learning provides an opportunity for students to actively participate in the construction of knowledge through authentic tasks, both as individuals and collaboratively to support in-depth learning [10]. Metaphors of knowledge-making or knowledge creation have also been used to describe the process of inquiry supported by the use of technology in advancing personal and communal knowledge [21].

Based on the literature review, Hew & Brush [22] concluded that effective professional development for technology integration requires focusing on content that includes (a) knowledge of technology and skills, (b) pedagogical knowledge supported by technology and skills (the ability to see clear relationships between technologies used and subject content taught), and (c) technology related knowledge and classroom management skills. Similarly, Kennedy notes that the most important features of a professional in development programs are a strong focus in helping teachers understand how students learn certain content, and how specific learning practices and tools can
support student learning outcomes [23]. So when introducing certain technological tools to in-service teachers, it is important for professional Development Programs to include information on how they can use the tool in a very specific way, within a particular content domain, and improve student learning outcomes. The Stage of teacher development, school development stage and TPACK are organized by Finger, et al as in Table 1.

| Stages of Teacher Development | Stages of School Development | Preservice Teacher Education Program |
|-------------------------------|------------------------------|--------------------------------------|
| Inaction                      | Traditional Industrial Age model of school organization | Focus on content Direct instruction Teacher-centered |
| Investigation                 | Early stages of understanding to enhance learning within existing curriculum and school organization | Focus on pedagogy and content Some interest in using ICT |
| Application                   | Exploration of digital technologies to enhance learning within existing curriculum and school organization | Focus on pedagogy and content Courses included in programs with focus on learning about ICT |

The Stage of teacher development, school development stage and TPACK are organized by Finger, et al as in Table 1.

2.5 What is the importance of Nature of Science (NOS)?

Holbrook & Rannikmae state that "An understanding of the Nature of Science (NOS) plays an important role in the development of scientific literacy" [25]. Understanding of NOS plays an important role in the development of science literacy. Furthermore, Abd-El-Khalick & BouJaoude state that "A scientifically literate person should develop an understanding of the nature of science"[26]. An understanding of NOS is defined as one of the expected characteristics of a person who has scientific literacy.

Understanding of NOS plays an important role in the development of science literacy. The three characteristics that are aspects of the NOS are: (1) the understanding that science is the result of creativity in the study of nature (the way of thinking); (2) an understanding that science is open to new discoveries and tentative knowledge (the way of investigating); (3) the understanding that science and technology are the results of human effort (the way of investigating and interaction technology-society).

2.6 What is Nature of Science (NOS)?

The understanding of NOS relates to whether the science is and how the science works. The underlying assumptions of scientific knowledge, how scientists function in social groups, and how the impact and response of society. This is a highlighted part of the science education reform. The conception of NOS itself is considered by teachers to change as long as the development of science and systematic thinking about the nature and way of working so that Nature of Science is tentative and dynamic [27; 28]. Lederman & Lederman define NOS as the values and assumptions inherent in scientific knowledge and the development of scientific knowledge [29]. Sangsaard & Thathong define NOS as the values and assumptions inherent in science, scientific knowledge, and the development of
scientific knowledge. This represents the unique characteristics of science by explaining and explaining what science is, how it works and how it differs from other disciplines, what scientists have done throughout history, and how science and scientists interact with society. Based on the definitions of these experts, it can be understood that Nature of Science (NOS) is a characteristic of the science itself [30].

2.7 What are the aspects of Nature of Science (NOS)?

NOS is included in Next Generation Science Standards (NGSS). NGSS Lead States (2013: 4) suggests that basic NOS understandings include: (1) Scientific investigation using a variety of methods; (2) Scientific knowledge based on empirical evidence; (3) Scientific knowledge is tentative; (4) Models, laws, mechanisms, and theories explain natural phenomena; (5) Science is a way of knowing; (6) Scientific knowledge assumes the direction and consistency of the natural system; (7) Science is a human endeavour; (8) Science aims to question the nature and the material world. These aspects of NOS will encourage students to have a passion and effort in using their thinking skills in the investigation. The effort can later develop students' literacy skills.

Lederman & Lederman (2004: 37) divides NOS into seven aspects. These aspects can be integrated into science curriculum and learning. The NOS aspect that Lederman & Lederman learners should understand can be seen in Table 2.

Table 2. Aspects of NOS according to Lederman & Lederman (2004)

| No. | Aspect of NOS                                                                 | Explanation                                                                                                                                 |
|-----|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | Important difference between observation result and inference result          | Observation result is a descriptive statement about natural phenomena that can be seen directly. In contrast, the inference result is a statement about a phenomenon that cannot be observed directly. The inference is obtained through the process of explanation and estimation of observations. |
| 2.  | The difference between scientific law and scientific theory                   | The scientific law is a statement or description of relationships among observable phenomena. The scientific theory contains explanations of the scientific law. |
| 3.  | Science is empirically                                                        | Science-based and/or derived from observations of natural phenomena.                                                                      |
| 4.  | Science involves imagination and human creativity                            | Imagination and creativity require scientists in designing an investigation, interpreting the results of an inquiry to produce an explanation, and bring up new ideas. |
| 5.  | Science is subjective (theory-laden)                                         | Factors that affect the performance of scientists in conducting investigations and interpreting the results of the investigation include commitment, trust, initial knowledge, training, experience, and expectations. |
| 6.  | Science affects and is influenced by social and cultural aspects             | Science affects and is influenced by various elements, such as politics, economics, philosophy, and religion. Cultural values also determine what and how science is done, interpreted, accepted, and used. |
| 7.  | Science is tentative                                                          | The science body in science (facts, concepts, principles, laws, and theories) may change with the discovery of new evidence.            |

2.8 How to learn about NOS?

Explicit NOS learning is superior to implicit by Bell, R, et al. in [31]. During this time the teaching of NOS in the course is still implicit. The results of NOS teaching are implicitly lower than explicit NOS teaching. The results of by Bell, et al. in [31] suggests that prospective teachers who experienced explicit instruction on NOS have statistically significant differences in their view of NOS rather than implicitly. The optimal NOS teaching for NOS understanding is done explicitly and reflectively by Lederman, et al., in [32], by Lederman in [33]. Hence, in this study will be developed NOS charge in the model of learning explicitly and reflectively so that NOS prospective teachers can be more optimal.
2.9 How to integrate NOS load in TPACK framework?

Based on the above reviews, it is important that innovations for science teacher education programs can produce science teachers with 21st-century demands. Innovation in the form of TPACK loaded NOS. NOS payload will provide TPACK uniqueness for the development of the quality of science teachers both preservice and in-service. Important NOS loads are added in the TPACK model, especially in the PCK component. The depiction of NOS within PCK as Figure 2.

![Figure 2. NOS within PCK](image)

Furthermore, the NOS-loaded TPACK framework model can be described as Figure 3 based on the synthesis of the references obtained.

![Figure 3. Framework NOS within TPACK](image)
3. Conclusion
Knowledge about integration technology in learning is very important mastered by the teacher to be able to adjust with the characteristic of technologically literate students. The knowledge of technology integration in learning is called TPACK, and it is also important to be given NOS within TPACK for service teacher education because NOS must be understood in a good way by pre-service and in-service science teacher. Innovation model framework “NOS within TPACK” is as an innovative idea for TPACK owned by science teachers both pre-service and in-service unique and can teach science as characteristic of science itself, so the ideal science learning can be realized.

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