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Teachers' Experiences in Implementing the Next Generation Science Standard Science Engineering Practice

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Abstract*—The Next Generation Science Standard (NGSS) is designed to shift how teaching framework from teaching facts to construct explanations from the phenomena. In particular, the science and engineering practices (SEPs) interrelate and represent the "knowledge and reasoning skill" necessary for students to build a rich network of connected ideas that serve as a conceptual tool for explaining phenomena, solving problems, and making decisions. However, knowledge and reasoning skills are less implemented during teaching process. Therefore, the aim of this research was to identify the profile of teacher experiences in implementing the NGSS SEPs in their learning process. This research was conducted by a descriptive research method. The number of participants involved in this research is 21 taken by random sampling technique. The data of teacher instructional practice was collected using teacher questionnaire concerned teacher instructional practice. The survey tool consists of 24 questions covering the following six areas of instructional practices with four of these are linking to the NGSS SEPs. The result revealed the lowest score was collecting data and analyze which is linked to NGSS SEPs 3-5 (planning and carrying out investigation, analyzing and interpreting data, and using mathematic and computational thinking), closely followed by instigating and investigating which is linked to NGSS SEPs 1 and 3 (asking question and defining problem, and planning and carrying out investigation. Modeling which is linked to NGSS SEPs 2 (developing and using model) and critique, explanation, and argumentation which is linked to NGSS SEPs 6-7 (constructing explanations and designing solutions, and engaging argument from evidence) have the same score in the higher level. Traditional instruction's score was relatively high and the highest score was prior knowledge. The result showed that teacher's experiences in learning process are dominated by traditional instruction and using student's prior knowledge. The teacher's experiences in implementing the NGSS SEPs is still rare. In order to help engaging students in the NGSS SEPs, instructional practices based on the NGSS SEPs need to be more implemented.

Keywords*—*next generation science standard; science and engineering practices; science instructional practices

I. INTRODUCTION

In the 21st century challenge, knowledge of science, technology and especially engineering are necessary to make informed decisions in most aspects of everyday life and the demand to fill jobs in these areas, especially engineering, is growing rapidly [1]. Integrating 21st century skill is not only beneficial for students and teachers, but also necessary to prepare the students for their future career [2]. Recent research has found that a majority of college students in Science, Technology, Engineering, and Mathematic (STEM)-related majors made their decision to study a STEM-related subject when they were in high school or even as early as middle school [3-4]. To address this problem, the Next Generation Science Standard (NGSS) integrate practice, engineering, and mathematic into science education [5-9].

The Next Generation Science Standard (NGSS) presents an opportunity to improve curriculum, teacher development, assessment and accountability, and ultimately student achievement [10]. The NGSS calls for significant educational shifting in science teaching framework that enable students to actively engage in scientific practices and apply crosscutting concept to core disciplinary ideas (DCIs) [11]. Teacher and administrators must recognize that the NGSS call for a shift away from teaching facts to students constructing explanations of phenomena [12] and from memorizing facts and following procedures towards more student-centered instruction [13]. Especially Science and Engineering Practices (SEPs) have given new emphasis to engage students in science. By using science and engineering practices in conjunction with DCIs and crosscutting concepts, students build a rich network of connected ideas that serves as a conceptual tool for explaining phenomena, solving the problem, making decisions, and acquiring new ideas from the previews network of ideas [14].

Preparing students for 21st Century challenges, a standardization organization of education in Indonesia called Badan Nasional Standard Pendidikan (BNSP) had formulated 16 learning principles that must be met in the 21st century education process, namely: (1) from teacher-centered to student-centered, (2) from one direction to interactive, (3) from isolation to a networking environment, (4) from passive to active-investigating, (5) from virtual / abstract to real-world contexts, (6) from personal to team-based learning, (7) from broad to typical behaviors empowering rules attachment, (8) from single-sense stimulation to all-round stimulation, (9) from a single device to a multimedia device, (10) from a one-way relationship shifting towards cooperative, (11) from mass production to customer needs, (12) from single conscious effort towards plural, (13) from one science and technology shifts to plural disciplinary knowledge, (14) from centralized control to autonomy and trust, (15) from factual to critical thinking, and (16) from the delivery of knowledge towards knowledge exchange [15]. Comparing to the shift of the NGSS, the shift that formulated by BNSP had the same goal that is to make an instruction more student-centered learning.

Inquiry is one of the learning approach which oriented to engage students participation (student-centered). Inquiry as a pedagogical approach was defined by the NRC as involving students in investigations and experimentations activities to "develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" [16]. But the definition of inquiry had been eluded in the research and practice doe to the lack of consistency in implementation [17-18]. Because of these vagueness meanings of the inquiry, in the 2011 NRC decided not to use the term inquiry. Then the NGSS SEPs was built from inquiry but it is more precisely defined in term of practices [19]. The recent study showed that the NGSS SEPs related to the instructional practice [20] (Table I).

TABLE I. THE ALIGNMENT OF INSTRUCTIONAL PRACTICE AND THE NGSS SEPS

Factor name of instructional practice		**The NGSS SEPs**	
Factor 1	Instigating an investigation	1, 3	Asking question and defining problems
			Planning and carrying out investigations
Factor 2	Data collection and analyze	3, 4, 5	Planning and carrying out investigations
			Analyzing and interpreting data
			Using mathematics and computational thinking
Factor 3	Critique, explanation, and argumentation	6, 7	Constructing explanations and designing solutions
			Engaging argument from evidence
Factor 4	Modeling	2	Developing and using models
Factor 5	Traditional instruction		
Factor 6	Prior Knowledge		

As the NGSS SEPs is linked to the practice of inquiry and engineering design, it is critical to know and support teachers in their implementation. High school teacher should be knowledgeable in how to support student in enacting the NGSS SEPs through the instructional practices. Even the teacher came from science background, teachers are "unlikely to have experienced authentic investigations that were closely integrated with core science ideas and crosscutting concepts as envisioned in the NGSS" [21]. In order to better support teachers in shifting instruction toward integrating the SEPs, it is important to know what teachers know with respect to the SEPs and build on those strengths. The next assessments tools about it should be prepared. Not only to assess the teachers knowledge but also the students ability in engaging science and practice. Because one of the successes of the teaching process can be seen from the assessments made for students [22].

Previous study that explored elementary teachers' PCK and confident in implementing the NGSS SEPs showed that teacher scored highest in SEPs 1 (Asking questions and defining problems) and the lowest score was in SEPs 8 (obtaining, evaluating, and communicating information) [23]. The study about how teachers used and adapted curriculum materials that included opportunities for students to engage in scientific practices had been conducted and found the teacher enacted almost every scientific practice in the curriculum, but in ways that varied from the written curriculum materials [24]. The other study figures out the difficulties found in-service teachers' understanding of developing and using models [25]. The same result that modeling or developing and using model is the least implemented but the traditional instruction was pretty often was found through survey research [20]. Every result in order to know the implementation of instructional practice in enacting the NGSS SEPs showed the differences. From the previous background, this study was conducted to identify the high school teachers' experiences in implementing instructional practice and engaging the NGSS SEPs.

II. METHOD

The purpose of this study was to identify the profile of teacher experiences in implementing the NGSS SEPs in their learning process. The study combined quantitative and qualitative approaches in two phases. The first phases, teachers were assessed for their PCK in enacting the NGSS SEPs using questioner. The survey instrument consisted of 24 items related to six areas of instructional practices, which four of them are linking to the NGSS SEPs (Table I). This survey items were adopted from Hayes who developed and validated a Science Instructional Practice survey instrument that is appropriate for the NGSS SEPs [20]. The teachers were asked to think about the typical units of instruction in their physics class and to rate how often students use the listed practice during the class. The 21 of high school physics teachers were responded to five-point Linkert rating system (i.e. never, rarely, sometimes, often, and always) measuring the frequency of instructional practice through self-report [26]. The teacher participants were selected by random sampling technique. Science every teacher's PCK in enacting the NGSS SEPs were not reported individually, but calculated by averaging the ratings of all practice items, and interpreting to the standard psychometric to report the internal reliability of the generated scale [27]. Cronbach's alpha, a measure of the internal consistency of instrument or subscale was used to analyze internal reliability for each area of instructional practices which were linked to the NGSS SEPs on the survey for self-rated knowledge. The internal consistency of an instrument, Cronbach Alphas were between 0.785 and 0.938. values of each practice were generally above 0.70 which indicates strong internal reliability for the self-report scales assessed by the survey (see Table II)

[20]. In the second phase, the interview method involved 6 teachers was conducted to gather more information about instructional practice in the classroom. The teacher participants were selected using purposing sampling technique.

TABLE II. THE IMPLEMENTATION OF INSTRUCTIONAL PRACTICE RANKS AND MEAN

Factor name	Rank	Mean	Cronbach's Alpha
Instigating an investigation	5	2.79	0.866
Data collection and analyze	6	2.59	0.933
Critique, explanation and argumentation	3	2.94	0.887
Modeling	4	2.92	0.938
Traditional instruction	2	3.02	0.785
Prior knowledge	1	3.39	0.901

III. RESULTS AND DISCUSSION

A. *The Profile of Teacher's Experiences in Implementing Instructional Practice*

The profile of teacher's experiences in implementing the science instructional practice is presented in Table II. The teacher's average score reported that the lowest score was Factor 1 (collection and analyze data) with mean score is 2.59. The second lowest rank was instigating an investigation with mean score is 2.79. The next lowest score was modeling with mean score is 2.92 closely followed by critique, explanation, and argumentation with mean score 2.94. The traditional instruction had the second highest score with mean score is 3.02. The highest score of teacher's experiences in implementing instructional practice was prior knowledge with average score is 3.39 indicating that prior knowledge was the most implemented in the classroom. Prior knowledge refers to the knowledge which includes facts, concepts, rules, principles, and relationship between concepts, rules, and principles in a specific domain. This type of knowledge is stored in an individual schema. Learning suffers if learners lack sufficient prior knowledge. Without prior knowledge, learners are limited in their ability to construct new knowledge [28].

TABLE III. THE NGSS OUTLINES EIGHT SCIENCE AND ENGINEERING PRACTICES (SEPs) ALIGNED TO INSTRUCTIONAL PRACTICES

Factor name	NGSS SEPs	Rank	Mean	Cronbach's Alpha
Instigating an investigation	1 and 3	5	2.79	0.866
Data collection and analyze	3, 4, and 5	6	2.59	0.933
Critique, explanation and argumentation	6 and 7	3	2.94	0.887
Modeling	2	4	2.92	0.938
Traditional instruction		2	3.02	0.785
Prior knowledge		1	3.39	0.901

B. *Instructional Practices Aligned to the NGSS SEPs*

The NGSS outlines eight science and engineering practices (SEPs) aligned to instructional practices (Table III). The NGSS SEPs 1 (asking question and defining problems) and SEPs 3 (planning and carrying out investigations) are related to the instructional practice Instigating an investigation. These practice activities including generating questions, choosing variables, and designing and implementing an investigation. Planning and carrying out investigations (SEPs 3) exhibited multidimensionality between factor 1 (instigating an investigation) and Factor 2 (data collection and analyze). Besides aligned to SEPs 3, Factor 2 (data collection and analyze) also aligned with SEPs 4 (analyze and interpreting data) and SEPs 5 (using mathematic and computational thinking). Factor 3 (critique, explanation, and argumentation) were aligned to SEPs 6 (constructing explanation and designing solution) and SEPs 7 (engaging in argument from evidence. Factor 4 (Modeling) related to SEPs 2 (developing and using models) including all items relate to modeling. Factor 5 (traditional instruction) was not aligned to any of NGSS SEPs. Traditional instruction was also known as conventional approach which was including direct instructions, demonstrations, and activity sheets [29]. The factor 6 is prior knowledge also was not aligned to any of the NGSS SEPs. Prior knowledge is necessary as an asset in the classroom to help engaging student's prior knowledge and real-world, home applications of science to bridge between science epistemologies and student experiences.

The profile of teacher in enacting the NGSS SEPs is presented in Table III. The result reported the lowest score of the NGSS SEPs was SEPs 3 (planning and carrying out investigations), SEPs 4 (analyzing and interpreting data), and SEPs 5 (using mathematic and computational thinking). These SEPs 3, 4, and 5 were linked to instructional practice Factor 2 which had the lowest score (M=2.59). The NGSS SEPs 3 appeared again as the second lowest rank along with the second lowest score of instructional practice was Factor 1 (instigating an investigation encompassing NGSS SEPs 1; asking questions and defining problems and 3; planning and carrying out investigations) with the mean score was 2.59. The NGSS SEPs 3 appeared again because it exhibited multidimensionality between Factor 1 and Factor 2. The two lowest ranked score of the instructional practice Factor, which both of them were included the NGSS SEPs 3 showed that SEPs 3 was the least implemented in the classroom. Investigations often designed by the teachers and the students followed the instruction about what to do in the classroom from teachers. The third lowest ranked was Factor 4 which was linked to the NGSS SEPs 2 (developing and using model) with the mean score of 2.92 closely followed by Factor 3 encompassing the NGSS SEPs 6 (constructing explanations and designing solution) and SEPs 7 engaging in argument from evidence). It showed that the most implemented instructional practice was Factor 3 which was linked to the NGSS SEPs 6 and 7 because the most implemented practice was by discussing and arguing about some problems that related to science. Although the gap score between the NGSS SEPs 6-7 and 2 was not significant.

The implementation of instructional practices in the classroom is less than traditional instruction. It was shown in the study that the mean score traditional instruction was relatively high (M=3.02), although not the highest because the highest mean score was prior knowledge (M=3.39). The teachers said that the time is the most constraint in implementing instructional practice which means in engaging the NGSS SEPs as well. Instead the time, most of teacher said that the material given in a year for each grade to huge when practice instruction applied.

IV. CONCLUSION

The purpose of this study was to identify the teacher's experiences in implementing instructional practice and engaging NGSS SEPs in their classroom. The result revealed that the most implemented instructional practice factor was prior knowledge and traditional instruction which were not linked to the NGSS SEPs. The less implemented of instructional practice factor was data collection and analyze which was linked to the NGSS SEPs 3 (planning and carrying out investigations), SEPs 4 (analyzing and interpreting data), and SEPs 5 (using mathematic and computational thinking). The NGSS SEPs with highest score was the NGSS SEPs 6-7 (constructing explanations and designing solutions – engaging in argument from evidence). The purpose of engaging in practice is to develop student's knowledge and understanding required by practice, how that practices contribute to how people know what they know, and how that practice helps to build reliable knowledge [30]. In this study, results showed that teachers had implemented the NGSS SEPs through the instructional practice. But the implementation had not been maximized and still dominated by traditional instruction and prior knowledge. In order to help engaging student in enacting the practice, the development of instructional practice designs is necessary. The next steps in professional development should focus on teacher's ability to foster understanding of the NGSS SEPs as much as their ability to enact the practices [23] the update tools for assessing these types of learning are also needed.

REFERENCES

[1] L.S. Hirsch, Suzanne Berliner-Heyman, John Carpinelli, Howard Kimmel, "Middle school students' understanding and application of the engineering design process", Frontiers in Education Conference (FIE) 2014 IEEE, pp. 1-6, 2014.

[2] H.A. Alismail, P. McGuire, "21st Century standard and curriculum: current research and practice," Journal of Education and Practices, vol.6, No.6, pp.150-154, 2015.

[3] Microsoft Corporation, STEM Perceptions: Student and Parent Survey, 2011.

[4] K. Cook, G. Wright, S. Shumway and R. Terry, "An Investigation Of Middle-School Students' Interest In, perception Of, And Attitudes About Technology And Engineering". Proceedings of the 2009 ASEE Annual Conference, Austin, TX, June 2009.

[5] S. Cavanagh, Panel Wants engineering Integrated into the Curriculum, Education Week, 2009.

[6] R.K. Coppola, and J. Malyn-Smith, Preparing for the Perfect Storm. Newton, MA: Education Development Center, Inc., 2006.

[7] D. Haller, "5 steps to STEM effectiveness" 2013 [Online]. Available: http:// www.huffingtonpost.com/douglas-haller/5-steps-tostem-effective_b_3561395.html access on 1 Septermber 2018.

[8] K. High, B. Hammack, B. Watt, J. Thomas, A. Redmond, P. Jordan, and J. Dockers, "A Middle School Project for Science and MathbEnhancement through Engineering". Proceedings of the 2009 ASEE Annual Conference, Austin, TX, June, 2009.

[9] S. Olds, C. Patel, B. Yalvac, D. Kanter, and N. Goel, "Developing a Standards-based K-12 Curricula through Partnerships with University Students and Industry". Proceedings of the ASEE Annual Conference, Salt Lake City, UT, 2004.

[10] R.W. Bybee, "NGSS and the next generation science teacher", J. Sci. Teacher Educ., pp.211-221, 2014.

[11] National Research Council (NRC), Next generation science standards: For states, by states, Washington: The National Academies Press, 2013.

[12] B.J. Reiser, What professional development strategies are needed for successful implementation of the Next Generation Science Standards?, 2013.

[13] O. Lee, H. Quinn, and G. Valdés, "Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics", Educational Researcher, vol. 42, 2013.

[14] J. Krajcik, S. Codere, C. Dahsah, R. Bayer, and K. Mun, "Planning instruction to meet the intent of the Next Generation Science Standards", Journal of Science Teacher Education, vol. 25, no.2, pp.157–175, 2014.

[15] Badan Standar Nasional Pendidikan, "Paradigma Pendidikan Nasional Di Abad-21". Jakarta: BSNP, 2010.

[16] National Research Council, "National science education standards", Washington, DC: The National Academies Press, 1996.

[17] R.D. Anderson, " Reforming science teaching: What research says about inquiry", Journal of Science Teacher Education, vol.13, pp.1–12, 2002.

[18] National Research Council (NRC), " A framework for K-12 science education: Practices, crosscutting concepts, and core ideas", Washington, DC: The National Academies Press, 2012.

[19] J.A. Vasques, "The NGSS science and engineering practice-an "8-point booster shot" for inquiry!," McGraw Hill Education.

[20] K.N. Hayes, C.S. Lee, R.D. Stefano, D.O'Connor, and J.C. Seitz, "Measuring Science Instructional Practice: A survey tool for the age of NGSS", J. Sci. Teacher Educ., vol.27, no.2, pp.137-164, 2016.

[21] National Academies of Sciences, Engineering, and Medicine, Science teachers' learning: Enhancing opportunities, creating supportive contexts. Washington, DC: National Academies Press, 2015.

[22] D. Ratnasari, Sukarmin, Suparmi, D. Harjunowibowo, "Analysis of science process skill pf summative test items in physics of grade X in Surakarta", Jurnal Pendidikan Indonesia, vol.7, no.1, pp.34-40, 2018.

[23] E.J.S. Kang, C. Donovan and M.J. McCarthy, "Exploring Elementary teachers' pedagogical content knowledge and confidence in implementing the NGSS science and engineering practices", Journal of Science Teacher Education, vol. 29, no.1, pp.9-29, 2018.

[24] A.S. Bismack, A.M. Arias, E.A. Davis, and A.S. Palincsar, "Connecting curriculum materials and teachers: Elementary science teachers' enactment of a reform-based curricular unit", Journal of Science Teacher Education, vol. 25, pp.489–512, 2014.

[25] R.S. Justi, and J.K. Gilbert, "Modeling, teachers' views on the nature of modeling, and implications for the education of modelers", International Journal of Science Education, vol.24, no.4, pp.369–387, 2002.

[26] G. Brown, "Measuring attitude with positively packed self-report ratings: Comparison of agreement and frequency scales. Psychological Reports, 2004(94), pp. 1015–1024, 2004.

[27] J.R.A. Santos," Cronbach's alpha: A tool for assessing the reliability of scales", Journal of Extension, vol.37, pp.1–5, 1999.

[28] H. Potelle, and J.F. Rouet, "Effect of Content Representation and Readers' Prior Knowledge on the Comprehension of Hypertext", International Journal of Human-Computer Studies, vol.58, pp.327, 2003.

[29] O. Lee, J. Maerten-Rivera, C. Buxton, R. Penfield, and W.G. Secada, "Urban elementary teachers' perspectives on teaching science to English language learners". J. Science Teacher Education, vol.20, pp.263, 2009.

[30] J. Osborne, "Teaching Sientific Practices: Meeting the Challenge of Change", Journal of Science Teacher Education, vol.25, pp.177, 2014.