

THE READINESS OF PRE-SERVICE INTEGRATED SCIENCE TEACHERS TOWARD THE NEXT GENERATION SCIENCE STANDARDS

Parmin Parmin *, Miranita Khusniati
Universitas Negeri Semarang, Semarang, Indonesia
*e-mail: parmin@mail.unnes.ac.id

Abstract: This research examined the readiness of pre-service integrated science teachers in Indonesia in following the dimensions of the next generation science standards. It employed a survey method combined with an examination of the readiness of pre-service integrated science teachers who are currently studying in five colleges in Indonesia. The survey collected the data from 218 respondents, consisting of managers of science education study programs, pre-service science teachers, science education lecturers, science teachers, school principals, and education practitioners. There were 131 pre-service science teachers participating in this study in addition to 40 science teachers with have more than seven years of service as a comparison. The survey instrument was designed and presented in the form of docs.google.com, consisting of 12 questions. Learning evaluation experts validated the instrument before it was administered to the respondents. This study found that pre-service science teachers were not prepared due to three aspects: mastery of concepts; digital literacy and teaching how to apply scientific concepts in life. The achievement of future science teacher criteria for pre-service teachers is higher than teachers, except for aspects of teaching skills and human literacy.

Keywords: Pre-service Integrated Science Teacher, Next generation science

KESIAPAN CALON GURU IPA TERPADU TERHADAP STANDAR IPA DI MASA MENDATANG

Abstrak: Penelitian ini mengkaji kesiapan calon guru IPA (Ilmu Pengetahuan Alam) terpadu di Indonesia dalam mengikuti dimensi standar IPA generasi mendatang. Metode yang digunakan adalah metode survei yang dikombinasikan dengan ujian kesiapan calon guru IPA terpadu yang sedang menempuh pendidikan di 5 perguruan tinggi di Indonesia. Survei ini mengumpulkan data dari 218 responden, yang terdiri dari pengelola program studi pendidikan IPA, calon guru IPA, dosen pendidikan IPA, guru IPA, kepala sekolah, dan praktisi pendidikan. Ada 131 calon guru IPA yang berpartisipasi dalam penelitian ini ditambah 40 guru IPA dengan masa kerja lebih dari tujuh tahun sebagai pembanding. Instrumen survei dirancang dan disajikan dalam bentuk docs.google.com, terdiri dari 12 pertanyaan. Ahli evaluasi pembelajaran memvalidasi instrumen sebelum diberikan kepada responden. Studi ini menemukan bahwa calon guru IPA tidak siap karena tiga aspek: penguasaan konsep; literasi digital, dan mengajarkan bagaimana menerapkan konsep-konsep ilmiah dalam kehidupan. Pencapaian kriteria guru IPA masa depan untuk calon guru lebih tinggi dari guru, kecuali aspek keterampilan mengajar dan literasi manusia.

Kata Kunci: calon guru sains terpadu, sains masa mendatang

INTRODUCTION

The previous studies of this field have found problems with the performance of science teachers graduating from teacher education programs since 2016 from three educational institutions in Indonesia: Universitas Negeri Semarang, Universitas Negeri Yogyakarta, and Universitas Negeri Surabaya. The science teacher profile with regards to pedagogical competence is good with a score of 85.7 out of 100 while for professional competency, it is average with a score of 65.4. Since professional competence relates to

the content of scientific knowledge, based on this preliminary study, graduates of teacher education in Indonesia are assumed to be good at teaching but weak in scientific content. Scientific knowledge as the main prerequisite must be fully mastered by each pre-service science teacher (Ahmad et al., 2019; Subramaniam, 2013; Wahyudiati et al., 2020). Mastery of scientific content also characterizes pre-service teachers who have a broad, deep, and integrated scientific knowledge.

Pre-service science teachers are expected to not only master extensive scientific content but

also integrate it with other scientific disciplines because of the increasingly complex problems in society (Michie et al., 2018; Rabin et al., 2012). A multidisciplinary approach in which science with technology are integrated to meet human needs is needed to make sure that the preparation of teachers in Indonesia today does not remain the same with that of 13 years ago. The preparation of science teachers in Indonesia so far refers to the standards in the Regulation of Minister of National Education (Permendiknas) No. 16 of 2007 (Masoka et al., 2017). After analyzing this regulation, it can be concluded that the teacher preparation lags far behind the needs of science teachers today. The existing criteria of ideal pre-service teachers do not require strong scientific mastery and are not yet oriented toward the needs of the current digital era. The solution to the lagging standard can refer to the next generation science standard because it has a science orientation in the future (NGSS Lead States, n.d.) but this standard also has not operationally described in the interests of preparing teacher candidates.

Multidisciplinary scientific mastery has, in fact, become a demand for present and future science in Indonesia with the birth of an integrated science curriculum. Integrating science, for example with technology, engineering, and mathematics, becomes very important and relevant to the needs of the community. Every pre-service science teacher must be equipped with the skills to be able to implement knowledge in the form of technology, with mastery of simple engineering and correct mathematical calculations. Integration of STEM (Science, Technology, Engineering, and Mathematics) elements in learning is an example that aims to widen the knowledge of pre-service science teachers. The preparation of pre-service science teachers, in addition to the demands of integrated science, also refers to the scientific characteristics of science in which truth is sought through scientific work.

This preliminary study proposes that pre-service science teacher's preparation programs need to integrate interdisciplinary science and have an orientation toward NGSS (Next Generation Science Standards) so that the demands of producing science teachers that are in line with future demands can be realized. The research aims to find out the strategy for preparing pre-service science teachers who not only master the knowledge but also have the skills to teach science that are oriented toward NGSS. The strategy must at least meet the NGSS dimension, namely: content, real-world science applications, and new

ideas about science. Science in NGSS (Bybee, 2013, 2014; Lederman & Lederman, 2014) covers eight aspects: investigation, empirical evidence, openness, scientific phenomena, a way, consistency, human effort, nature, and the world. The eight aspects can be modified in the interest of preparing standards for pre-service science teachers.

Science with an interdisciplinary approach aims to have analytical and mathematical abilities to solve real problems (Breiner et al., 2012; English, 2017; Howard & Ifenthaler, 2018; Williams et al., 2015; Wu & Anderson, 2015). An interdisciplinary approach is needed because it connects between the school and the industry, so it requires the preparation of pre-service science teachers who are broad-minded and product oriented. Science learning develops knowledge and practices of life skills and technology. Pre-service teachers must be trained to apply concepts to create, produce, and maintain learning in the digital age. The integrated science is designed systematically starting from the teacher's knowledge to the use of knowledge-oriented learning strategies about entrepreneurship. The application of integrated science in schools is part of preparing an independent generation by growing positive attitudes towards the modern industrial world (Jehopio & Wesonga, 2017). In its implementation, teachers need to develop multidisciplinary-oriented learning tools that have an impact on the student's independence. All elements in integrated learning make knowledge meaningful (Shernoff et al., 2017).

Soobard and Rannikmäe (2011), Buckley, O'Connor, Seery, Hyland, & Canty, (2019), and Dewi, Khery, and Erna (2019)(2019) state that the skills to work scientifically can be developed by providing exercises for studying cross-sectoral learning resources due to the characteristic of learning resources which is contextual. Critical attitudes can be developed through learning resources from the community that have their appeal, so they need to be formalized in the form of a modern science curriculum (Bybee, 2014). A critical attitude is created from the practice of conducting investigations, in line with the Huang and Asghar study, (2016) which suggests that the activity of inquiry in science needs to become a culture as an object of study. Sjöström (2018) argues that scientific literacy is obtained by integrating science as scientific knowledge with community traditions that are following the characteristics of scientific objects. Faisal & Martin (2019) and Gomes & Fleer (2019) state that how

scientific work is needed for pre-service science teachers as a provision to facilitate student learning that integrates science in life.

The analysis of scientific literacy from Allchin study (2014) proves that strong scientific literacy is based on the ability to analyze learning resources that have concrete facts. To develop literacy skills, providing a real study object is needed, in line with the Archer-Bradshaw, (2017) and She, Stacey & Schmidt, (2018) studies which found that literacy is built from personal knowledge that is developed by providing training in making scientific decisions taken through discovery activities in practice. Opportunities to

discover scientific knowledge can provide positive assessments toward scientific knowledge, as stated by Trauth-Nare (2016) that scientific literacy is built by giving broad access to find, debate, and discuss findings, as well as give a positive assessment toward science. Positive assessment toward science depends on the way the teacher uses learning strategies for achieving competence, which is in line with Hsieh, Lin, Liu, & Tsai (2019) who state that selected learning strategies using contextual learning resources from the environment and direct community life are more likely to foster motivation to learn science.

Table 1. The profile of NGSS-Oriented Science Teacher Standards in Indonesia

NGSS NOS Category (the Lead States, 2013)	The Competency of Science Teachers in Indonesia (Permendiknas No. 16 of 2007)	The Profile of Pre-service Science Teachers oriented to NGSS
<ol style="list-style-type: none"> 1. Scientific investigation uses various methods. 2. Scientific knowledge is based on empirical evidence. 3. Scientific knowledge is open to revision by considering new evidence. 4. Models, laws, mechanisms, and theories from science explain natural phenomena. 5. Science is a way of knowing. 6. Scientific knowledge assumes order and consistency in natural systems. 7. Science is a human endeavor. 8. Science answers questions about the natural and material environment. 	<ol style="list-style-type: none"> 1. Understand the concepts, laws, and theories of Natural Sciences and their application flexibly. 2. Understand the science thinking process in studying natural processes and phenomena. 3. Use symbolic language in describing natural processes and phenomena. 4. Understand the relationships between the various branches of science, and the relationship between science and mathematics and technology. 5. Think qualitatively and quantitatively about simple natural law and processes. 6. Apply scientific concepts, laws, and theories to explain various natural phenomena. 7. Explain the application of scientific laws in technology especially those that can be found in everyday life. 8. Understand the scope and depth of school science. 9. Creative and innovative in the application and development of science. 10. Master the principles and theories of management and learning/work safety in the school's science laboratory. 11. Use measuring instruments, teaching aids, calculating tools, and computer software to improve science learning in classrooms and laboratories. 12. Design scientific experiments for learning or research purposes. 13. Carry out scientific experiments in the right way. 14. Understand the history of the development of science and the thoughts that underlie these developments. 	<ol style="list-style-type: none"> 1. Mastering broad and deep scientific content. 2. Competent in teaching science with information technology devices. 3. Digital literacy to organize online learning. 4. Humanitarian literacy by applying science content to humanity. 5. Competent in integrating science in a multidisciplinary way to solve problems. 6. Performing scientists always consistently apply scientific methods.

Based on the results of preliminary studies and previous research, this research aims to produce standards and measure the readiness of pre-service science teachers in Indonesia who have NGSS-oriented teaching skills. The NGSS dimension in detail has described clear boundaries about the scientific knowledge needed in the future, which is more detailed, operational, and simplified by integrating interests in the preparation of pre-service science teachers in Indonesia. The Regulation of National Education Minister number 16 of 2007 requires relatively low competence of science teachers because it puts a heavy emphasis on normative demands like any other teachers in other fields. This study adopts the NGSS category with the competency criteria of integrated science teachers in Indonesia to find the profile of future science teachers oriented to NGSS. The standards of pre-service science teachers after conducting a critical review of NGSS and science teacher competencies are as shown in Table 1.

The standard of science teachers in Indonesia as stipulated in Permendiknas No. 16 of 2007 is not following the criteria stated in the NGSS. It is important and urgent to immediately develop new standards that refer to the NGSS because the educational process of preparing pre-service science teachers continues to run and produce thousands of new graduates. It is feared that if new standards are not immediately developed, education in Indonesia, especially science, will increasingly lag behind other countries.

The tested projected application of NGSS in future science education in the US has implications for the teaching process and teachers' readiness to provide solutions for increasingly professional science teachers (Lederman & Lederman, 2014). The uniqueness of standard science provides more excellent room for each generation studying science to be served in the same ways. Lee et al., (2014) stated that science teaching does not differentiate the students' backgrounds and does not classify them based on their learning speed. Curriculum integrating NGSS has been used in 19 US states because it fits the learning needs oriented towards monitoring science learning progress (Watson et al., 2021). A standardized preparation of pre-service science teachers is needed through an educational process that refers to indicators of future science learning. Science education reform carried out by NGSS requires the skills of prospective science teachers at the undergraduate level who can master

science content according to future needs (Bybee, 2014).

The problem of this research is how the readiness of pre-service integrated science teachers oriented in the Next Generation Science Standards.

METHODS

Research Design

The study used a survey method adopted from Sugiyono (2017). The survey results are followed up by measuring the readiness of pre-service science teachers.

Participants

There were 131 pre-service science teachers participated in this study. They are currently studying at Universitas Negeri Semarang, Universitas Pancasakti Tegal, Universitas Negeri Surabaya, Universitas Negeri Yogyakarta, and Universitas Islam Negeri Raden Intan Lampung. The research participants include pre-service science teachers, lecturers, and managers of science education study programs as well as science teachers, school principals, and education practitioners interested in studying the preparation of pre-service teachers in Indonesia.

Data Collection

The study used a survey method adopted from Sugiyono (2017). The survey results were followed up by measuring the readiness of pre-service science teachers.

Data Collection Tools

The survey instrument was made in the form of docs.google.com consisting of 12 question items. The experts of learning evaluation validated the instrument before it was given to the respondents. After the instrument was declared valid, it was given to all respondents.

The survey had drawn the opinions of 218 participants which consisted of 15 managers of science education study programs, 131 pre-service science teachers, 44 science education lecturers, 18 science teachers, 5 school principals, and 4 education practitioners. The managers of the study programs were actively preparing the education of pre-service science teachers so that they have experience in the process of producing pre-service teachers. Pre-service science teachers involved were those who were, at the time, active students while the lecturers were the ones carrying out the preparation pre-service science teachers. Science teachers participating in this study were still teaching at school with the school principals having a background in science education.

Meanwhile, the education practitioners were those who were motivated to provide ideas and thoughts. The survey of respondents was very important to get input about the criteria of science teachers. The survey results were used as a reference to develop instruments for measuring the readiness of pre-service science teachers in five colleges in Indonesia.

The references used to determine the profile of pre-service science teachers were obtained from the national standards of science teachers and the standard dimensions in the NGSS. Both references were used to determine the criteria for future science teachers in Indonesia. The research flow chart was presented in Figure 1.

Respondents received 12 questions ranging from knowledge of national standards to that of international standards of science teachers. The questions were about the importance of new standards for preparing science teachers. With their own experiences, all respondents were asked to provide an assessment of the mastery of the materials, teaching skills, digital literacy skills, and the humanitarian literacy skills of science teachers who were currently teaching in school. All respondents were asked about their satisfaction level towards the existing teacher performance in schools. The questions given pointing to the criteria of future science teachers. Successfully formulated criteria were used to examine the readiness of pre-service science teachers who were currently in the study process.

The instrument used in this study was adjusted to the NGSS-oriented technique to measure the readiness of pre-service science teachers. The main data source of the in-depth questionnaire revealed the profile of future science teachers using in-depth interviews. Data that found the

readiness of science pre-service teachers was obtained from combining the two main sources.

Data Analysis

The survey data were analyzed descriptively by explaining the aspects that were asked in the questionnaire. The survey results were obtained in detail about the criteria that must be met by science teachers. Data analysis began with the validation of data from the respondents to determine the frequency, percentage, and valid percentage. In the instrument, there were entries about the criteria for future science teacher profiles. The data were presented descriptively. The data analysis of the readiness of pre-service science teachers were processed with the SPSS program to further obtain data on the level of readiness of content mastery, teaching skills, digital literacy, humanitarian literacy, integrated science, learning media, HOTS, and science applications.

This research collected data for eight future science teacher criteria from science teachers in schools. The data were used to compare future science teacher criteria in pre-service teachers. The target of the survey was teachers who had taught more than seven years but graduated from programs other than the science education such as chemistry education, biology education, or physics education. There were 40 target teachers consisting of 12 men and 28 women. The data were analyzed descriptively to find the percentage for each criterion. The comparison of achievement of future science teacher criteria between pre-service teachers and teachers was obtained based on this data. The questionnaire resulted from in-depth interviews were used to obtain the profile of future science teachers expected by pre-service science teachers.

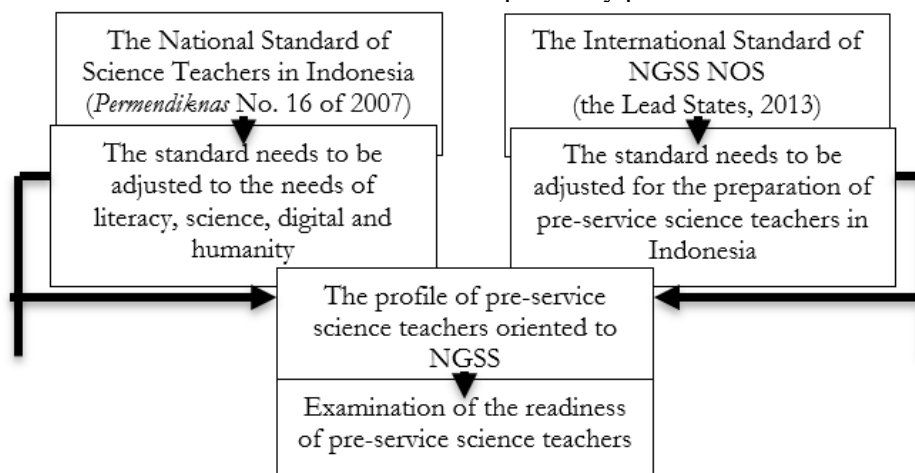


Figure 1. Research Framework

FINDINGS AND DISCUSSION

Findings

The respondents voluntarily participated in this research after the researchers gave the summary of the research through an online discussion. It was necessary to do so to make sure that they understood the objectives and urgency of this study.

The survey instrument was made in the form of docs.google.com consisting of 12 question items. The experts of learning evaluation validated the instrument before it was given to the respondents. The experts review consisted of one professor and two Doctors of Science Education. They were asked to evaluate the validity of the survey instruments given to the respondents. Mean scores ranged from 3.1 to 3.9 on a scale of 1 to 4, with 1 indicating "strongly disagree" and 4 indicating "strongly agree". The average congruency percentage (ACP) is 93%, which indicates that the instrument is valid (Popham, 1978).

The respondent validation in this study was analyzed to inform that there was no problem with the involvement of respondents consisting of six parties. The research respondents consider the role in determining the standard criteria for pre-service science teachers that are the focus of

the findings in this study. The data from 218 respondents are all valid with the results of the complete analysis in Table 2.

Analyzing Respondents' Input

After the questionnaire was filled out by 218 respondents, it was concluded valid. The next was analyzing the results of each respondent's input in relation to the expected criteria for future science teachers. A summary of the expected science teacher profiles according to the respondents is presented in Table 3.

Measuring Students' Readiness

The analysis of the profile of future science teachers from the respondents suggests the existence of a new standard of science teachers in Indonesia. Existing standards were now far from the needs and demands of scientific and technological development. The new standard was best tried on the preparation of pre-service teachers who are currently studying in several colleges in Indonesia. After getting input from the respondents about the profile of science teachers, it was continued by measuring the readiness of 131 students who were studying at the time as pre-service science teachers. Student readiness based on the criteria for future science teachers is presented in Figure 2.

Table 2. The analysis of respondent questionnaire validity

		Frequency	Percent	Valid Percent
Valid	Science Education Lecturers	44	20	20
	The Head of Science Education Study Program	15	7	7
	In-Service Science Teachers	19	9	9
	Pre-service Science Teachers	131	60	60
	School Principals	5	2	2
	Education Practitioners	4	2	2
	Total	218	100,0	100,0

Table 3. The profile of the expected future science teachers

Profile Aspects	The description of the expected profile
Science content knowledge	<ul style="list-style-type: none"> ▪ Mastering science content not limited to teaching needs, but always updating their knowledge through reading trusted journal articles. ▪ Reinforcing content in broader forms of application in human life so that science truly becomes a unified knowledge in life.
Teaching skill	<ul style="list-style-type: none"> ▪ Presenting the materials using information technology tools to proficiently carry out online learning. ▪ Being competent and confident to develop supplementary teaching materials developed by teachers with local wisdom characteristics.
Digital Literacy	<ul style="list-style-type: none"> ▪ Being competent in using application programs to organize online learning.
Humanitarian literacy	<ul style="list-style-type: none"> ▪ Encouraging students to be able to apply science to humanitarian missions. ▪ Being competent in making science a healthy and environmentally friendly lifestyle.
Multi-disciplinary capability	<ul style="list-style-type: none"> ▪ Integrating knowledge across fields in solving science problems.
Performance satisfaction	<ul style="list-style-type: none"> ▪ Working like a scientist by always consistently applying scientific methods.

The readiness of pre-service integrated science teachers...

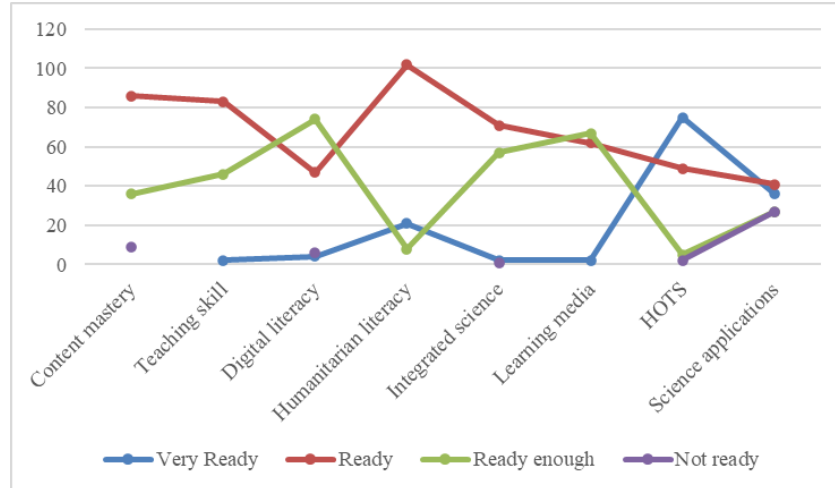


Figure 2. Student readiness based on the criteria of future science teachers

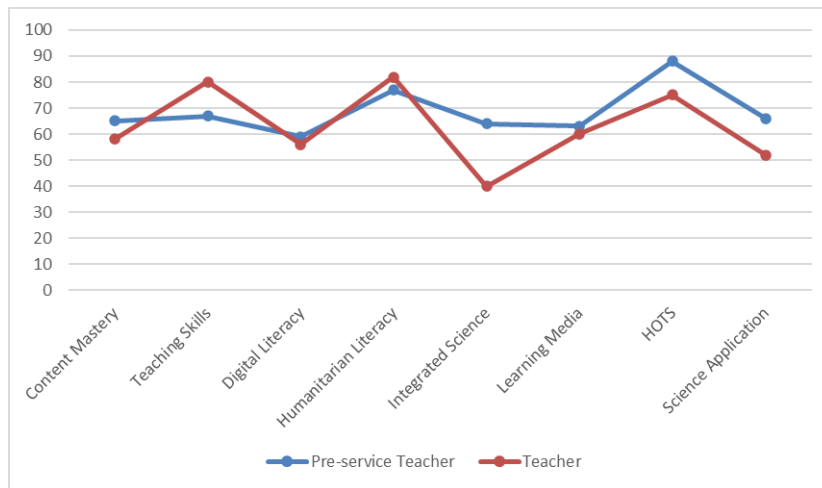


Figure 3. Achievement Comparison of Future Science Teachers Criteria Between Pre-service Teachers and In-service Teachers

None of the pre-service science teachers was very ready in terms of content mastery even some were not ready at all. In terms of digital literacy, of 131 prospective science teachers, six of them were not ready with the demands of organizing science learning using information technology devices. Pre-service science teachers have a great commitment to the application of science to humanity because all is prepared for this aspect. There were 27 students who were in the category of “not ready” in terms of the science application.

The next analysis was related to the comparison of readiness between pre-service teachers and teachers with more than seven years of teaching experiences. The comparison analysis of eight aspects of future science teachers’ criteria is presented in Figure 3.

The content mastery of pre-service teachers from the educational background was better than that of the current science teachers. The difference in content mastery was because the current science teachers at schools were not prepared

with integrated science, but only one field of science, that was seen from the result of the integrated science aspect. The teachers were not ready, with the score of 40, and the pre-service teachers were in a “ready” category, with the score of 64. Current teachers had a higher score in aspects related to teaching experiences, such as teaching skills and humanitarian literacy.

Discussion

The demand for pre-service science teachers who were oriented towards next generation science standards begins with having knowledge of science content that was always updated through the use of various reliable literature. Isozaki (2018) and Wei (2019) stated that content mastery becomes the main prerequisite for quality science education. The content was strengthened in the wider forms of application in human life so that science truly becomes knowledge that was integrated with life. The quality of learning material of the preparation of pre-service science teachers was currently less than 75% for

scientific aspects. This becomes an inhibiting factor so that no one was very ready for the aspect of content mastery. There was an assumption in the community that pre-service science teachers who are trained in some colleges in Indonesia were known to have teaching skills but not content mastery, which can be justified from the findings of this study.

Pre-service science teachers currently have good teaching skills. They have obtained learning provisions to prepare a material presentation using information technology tools in online learning. The readiness of the pre-service teachers, after being explored as an impact of the habits of lecturers in providing learning materials, is shown in how they are accustomed to using online learning. The habits of lecturers were proven to be essential in providing role models for pre-service teachers. Teaching skills are formed from learning habits during education for pre-service teachers (Siew et al., 2015). Assignments in the form of developing material during learning have an impact on having a strong desire to be able to develop teaching materials that integrate local wisdom.

Two literacy skills should be learned by pre-service science teachers. After the confirmation on each respondent, they had various digital literacy readiness. Some pre-service teachers had very limited knowledge about application programs for presenting online materials. Pre-service teachers were not only limited to being able to present material with information technology devices but also were required to be able to socialize, behave, think and inspire as digital competencies. Digital literacy made access to the latest learning resources easy to find (Nouri, 2019). Humanitarian literacy must also be owned by pre-service teachers. The readiness of pre-service science teachers in human literacy was found to be better than digital literacy. Seroglou & Adúriz-Bravo, (2012) state that science is applicable and integrated with human life. There was a strong commitment from every pre-service teacher to apply science in humanitarian missions and to make science unified with life.

Every pre-service science teacher was a scientist in charge of preparing for the birth of a new scientist. Problems in life were increasingly complex. Science as a way to solve problems required integration across many fields. Problem solving in science is more easily solved when connected with other fields of study in an integrated manner (Dare et al., 2018). When this research was conducted, the lecturers who prepared

pre-service teachers were mostly from the field of science, for example, biology, physics, and chemistry. This became an inhibiting factor for students to integrate with other scientific fields. The readiness of pre-service teachers to integrate scientific knowledge requires extensive insight. The data shows that there were 27 (20%) students who were certainly not ready to teach how to apply science in life.

The readiness of pre-service teachers in evaluating science learning that meets the principles of the Higher Order Thinking Skills (HOTS) was still in the “quite ready” category. Thinking skills were the focus of preparation of pre-service teachers in Indonesia because students in Indonesia can think that it was still low (from the findings of the Program for International Student Assessment in 2018). According to science teachers at schools, it was revealed that the existing assessment method has indeed been a burden for teachers. Teachers believed that learning science was conducted more effectively through experiments and scientific activities, but they found it difficult to carry out the theory of scientific truth because the assessment was too intervened by the government. Limniou et al., (2018) argued that HOTS trains students' way of thinking to solve problems with existing learning experiences. Pre-service teachers needed to be equipped with the courage to develop their assessments equipped with HOTS theory.

In the achievement of future science teachers' criteria between pre-service teachers and in-service teachers (Figure 2), there were six out of eight aspects of future science teachers' criteria in which pre-service teachers achieved higher score. Science teachers from science education had better skills than the current teachers at schools. Pre-service teachers were science education students who were prepared with the necessary skills for science teachers, such as the skill of content and integration of science fields (chemistry, physics, biology, and astronomy). The content mastery of pre-service teachers from the educational background was better than the current science teachers. The difference in content mastery was because the current science teachers at schools were not prepared with integrated science, but only one field of science, that was seen from the result of the integrated science aspect. The teachers were not ready with the score of 40, and the pre-service teachers were in a “ready” category with the score of 64.

The science education program has been offered by many universities in Indonesia since

2009. The science education program in that year was functioned as a preparation step towards the 2013 Curriculum, in which there were several integrated subjects, one of which was Natural Science (Prihantoro, 2015). On the other hand, science teachers with more than seven years of service have only a basis in one of the science fields. This study found that science teachers were weak in content mastery and content integration. This reinforces the importance of educating pre-service teachers following the scientific field. It means that the science teachers' education background was not a field-based education, for example, biology, physics, or chemistry.

Pre-service teachers were prepared not only with science content skills and its integration, but also with digital literacy, including preparing learning media. Skills in preparing learning media have a positive impact on students' achievements (Agustiya et al., 2017; Astra et al., 2015; Widiensyah et al., 2018). The finding of this study is that pre-service teachers have better future science teachers' criteria. Future science teachers are not obtained naturally but through programmed preparation of pre-service teachers. Current teachers had a higher score in aspects related to teaching experiences, such as teaching skills and humanitarian literacy.

This research has limitations because it did not do treatments with the criteria for future science teachers that have been formulated. The research findings were not based on the effectiveness of a special treatment given to pre-service science teachers in Indonesia. The study confirmed the importance of preparing pre-service science teachers in Indonesia with new standards that are in line with the dimensions of next generation science standards. It changed the orientation of the balance between the way to teach with the content being taught become emphasizing more on mastering the scientific content of science. Teaching skills that were not previously used for online classrooms was altered by proficiently presenting online learning. Science that was taught as an independent scientific field is changed by a multidisciplinary scientific approach so that the knowledge of every pre-service science teacher becomes broader.

The findings of teachers' readiness were weak on concept mastery, teaching skills, and digital literacy. Following the NGSS characteristics, this study recommended strengthening the education curriculum of pre-service science teachers. Strengthening the curriculum was important in the preparation of teaching internships

and professional certification. Teaching internship at school that requires three skills of pre-service teachers becomes the standardized parameter of science teaching readiness. The participation of pre-service teachers in professional certification of digital literacy was needed before teaching internships.

CONCLUSION

After taking examinations in five colleges, it could be concluded that pre-service teachers are not ready in three aspects including concept mastery, digital literacy, and teaching how to apply science concepts in life. It was expected to use these findings as a recommendation to create new competency standards for science teachers in Indonesia and to use them in developing new standards.

RECOMMENDATIONS

Based on the results of this study, the standard of science teachers in Indonesia requires treatments so that they have a broad and deep mastery of science content, digital-literacy teaching skills, humanitarian literacy skills, an ability to integrate science in multidisciplinary scientific ways to solve real problems in society and perform as scientists do.

REFERENCES

- Agustiya, F., Sunarso, A., Education, S. H.-J. of P., & 2017, U. (2017). Influence of CTL model by using monopoly game media to the students' motivation and science learning outcomes. *Journal of Primary Education*, 6(2), 114–119. <https://doi.org/10.15294/jpe.v6i2.17559>
- Ahmad, N., Ishak, N., ... M. S.-J. P., & 2019, undefined. (2019). Pre-Service Science Teachers in International Teaching Practicum: Reflection of the Experience. *Journal.Unnes.Ac.Id*, 8(3), 308–316. <https://doi.org/10.15294/jpii.v8i3.18907>
- Allchin, D. (2014). From Science Studies to Scientific Literacy: A View from the Classroom. *Science and Education*, 23(9), 1911–1932. <https://doi.org/10.1007/S11191-013-9672-8>
- Archer-Bradshaw, R. E. (2017). Teaching for scientific literacy? An examination of instructional practices in secondary schools in barbados. *Research in Science Education*, 47(1), 67–93. <https://doi.org/10.1007/s11165-015-9490-8>

- x
- Astra, I. M., Nasbey, H., & Nugraha, A. (2015). Development of an android application in the form of a simulation lab as learning media for senior high school students. *EURASIA Journal of Mathematics, Science and Technology Education, 11*(5), 1081–1088. <https://doi.org/10.12973/eurasia.2015.1376a>
- Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion About conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3–11. <https://doi.org/10.1111/j.1949-8594.2011.00109.x>
- Buckley, J., O'Connor, A., Seery, N., Hyland, T., & Canty, D. (2019). Implicit theories of intelligence in STEM education: Perspectives through the lens of technology education students. *International Journal of Technology and Design Education, 29*(1), 75–106. <https://doi.org/10.1007/s10798-017-9438-8>
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunity*. National Science Teachers Association (NSTA) Press.
- Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education, 25*(2), 211–221. <https://doi.org/10.1007/s10972-014-9381-4>
- Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education, 5*(1), 4. <https://doi.org/10.1186/s40594-018-0101-z>
- Dewi, C. A., Khery, Y., & Erna, M. (2019). An ethnoscience study in chemistry learning to develop scientific literacy. *Jurnal Pendidikan IPA Indonesia, 8*(2), 279–287. <https://doi.org/10.15294/jpii.v8i2.19261>
- English, L. D. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education, 15*(S1), 5–24. <https://doi.org/10.1007/s10763-017-9802-x>
- Faisal, & Martin, S. N. (2019). Science education in Indonesia: Past, present, and future. *Asia-Pacific Science Education, 5*(1), 4. <https://doi.org/10.1186/s41029-019-0032-0>
- Gomes, J., & Flear, M. (2019). The development of a scientific motive: How preschool science and home play reciprocally contribute to science learning. *Research in Science Education, 49*(2), 613–634. <https://doi.org/10.1007/s11165-017-9631-5>
- Howard, N. R., & Ifenthaler, D. (2018). Integrating STEM opportunities for young learners. *Technology, Knowledge and Learning, 23*(2), 195–197. <https://doi.org/10.1007/s10758-018-9364-1>
- Hsieh, F.-P., Lin, H., Liu, S.-C., & Tsai, C.-Y. (2019). Effect of peer coaching on teachers' practice and their students' scientific competencies. *Research in Science Education*. <https://doi.org/10.1007/s11165-019-9839-7>
- Huang, Y.-S., & Asghar, A. (2016). Science education reform in confucian learning cultures: Policymakers' perspectives on policy and practice in Taiwan. *Asia-Pacific Science Education, 2*(1), 3. <https://doi.org/10.1186/s41029-016-0010-8>
- Isozaki, T. (2018). Science teacher education in Japan: Past, present, and future. *Asia-Pacific Science Education, 4*(1), 10. <https://doi.org/10.1186/s41029-018-0027-2>
- Jehopio, P. J., & Wesonga, R. (2017). Polytechnic engineering mathematics: Assessing its relevance to the productivity of industries in Uganda. *International Journal of STEM Education, 4*(1), 16. <https://doi.org/10.1186/s40594-017-0078-z>
- Lederman, N. G., & Lederman, J. S. (2014). The next generation science standards: Implications for preservice and inservice science teacher education. *Journal of Science Teacher Education, 25*(2), 141–143. <https://doi.org/10.1007/s10972-014-9382-3>

- Lee, O., Miller, E. C., & Januszyk, R. (2014). Next generation science standards: All standards, All students. *Journal of Science Teacher Education*, 25(2), 223–233. <https://doi.org/10.1007/s10972-014-9379-y>
- Limniou, M., Schermbrucker, I., & Lyons, M. (2018). Traditional and flipped classroom approaches delivered by two different teachers: The student perspective. *Education and Information Technologies*, 23(2), 797–817. <https://doi.org/10.1007/s10639-017-9636-8>
- Masoka, M., Ibrohim, & Indriwati, S. E. (2017). Studi eksplorasi kualifikasi dan kompetensi guru bidang studi biologi SMP—SMA sebagai basis program peningkatan kualitas pendidikan. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, 2(4), 516–523. <https://doi.org/http://dx.doi.org/10.17977/jptpp.v2i4.8771>
- Michie, M., Hogue, M., & Rioux, J. (2018). The application of both-ways and two-eyed seeing pedagogy: Reflections on engaging and teaching science to post-secondary indigenous students. *Research in Science Education*, 48(6), 1205–1220. <https://doi.org/10.1007/s11165-018-9775-y>
- NGSS Lead States. (n.d.). *Next generation science standards: For states, by states*. National Academies Press.
- Nouri, J. (2019). Students multimodal literacy and design of learning during self-studies in higher education. *Technology, Knowledge and Learning*, 24(4), 683–698. <https://doi.org/10.1007/S10758-018-9360-5>
- Popham, W. J. (1978). *Criterion-referenced measurement*. Prentice Hall.
- Prihantoro, C. R. (2015). The perspective of curriculum in Indonesia on environmental education. *International Journal of Research Studies in Education*, 4(1). <https://doi.org/10.5861/ijrse.2014.915>
- Rabin, B. A., Purcell, P., Naveed, S., Moser, R. P., Henton, M. D., Proctor, E. K., Brownson, R. C., & Glasgow, R. E. (2012). Advancing the application, quality and harmonization of implementation science measures. *Implementation Science*, 7(1). <https://doi.org/10.1186/1748-5908-7-119>
- Seroglou, F., & Adúriz-Bravo, A. (2012). Introduction: The application of the history and philosophy of science in science teaching. In *Science and Education* (Vol. 21, Issue 6, pp. 767–770). <https://doi.org/10.1007/s11191-011-9394-8>
- She, H. C., Stacey, K., & Schmidt, W. H. (2018). Science and Mathematics Literacy: PISA for Better School Education. *International Journal of Science and Mathematics Education*, 16. <https://doi.org/10.1007/S10763-018-9911-1>
- Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, 4(1), 13. <https://doi.org/10.1186/s40594-017-0068-1>
- Siew, N. M., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *SpringerPlus*, 4(1), 1–20. <https://doi.org/10.1186/2193-1801-4-8>
- Sjöström, J. (2018). Science teacher identity and eco-transformation of science education: Comparing Western modernism with Confucianism and reflexive Bildung. *Cultural Studies of Science Education*, 13(1), 147–161. <https://doi.org/10.1007/s11422-016-9802-0>
- Soobard, R., & Rannikmäe, M. (2011). Assessing student's level of scientific literacy using interdisciplinary scenarios. *Science Education International*, 22(2), 133–144. <https://eric.ed.gov/?id=EJ941672>
- Subramaniam, K. (2013). Minority preservice teachers' conceptions of teaching science: sources of science teaching strategies. *Research in Science Education*, 43(2), 687–709. <https://doi.org/10.1007/S11165-012-9284-3>
- Sugiyono. (2017). *Metode penelitian kuantitatif, kualitatif dan R&D*. Alfabeta.

- Trauth-Nare, A. (2016). Re-envisioning scientific literacy as relational, participatory thinking and doing. *Cultural Studies of Science Education*, 11(2), 327–334. <https://doi.org/10.1007/s11422-015-9676-6>
- Wahyudiati, D., Rohaeti, E., Irwanto, Wiyarsi, A., & Sumardi, L. (2020). Attitudes toward chemistry, self-efficacy, and learning experiences of pre-service chemistry teachers: Grade level and gender differences. *International Journal of Instruction*, 13(1), 235–254. <https://doi.org/10.29333/iji.2020.13116a>
- Watson, S. W., Shan, X., George, B. T., & Peters, M. L. (2021). Alignment of select elementary science curricula to the next generation science standards via the EQUIP rubric. *Curriculum Perspectives*, 41(1), 17–26. <https://doi.org/10.1007/S41297-021-00131-X>
- Wei, B. (2019). Science teacher education in Macau: A critical review. *Asia-Pacific Science Education*, 5(1), 10. <https://doi.org/10.1186/s41029-019-0036-9>
- Widiansyah, A. T., Indriwati, S. E., Munzil, M., & Fauzi, A. (2018). I-invertebrata as an android-based learning media for molluscs, arthropods, and echinoderms identification and its influence on students' motivation. *Jurnal Pendidikan Biologi Indonesia*, 4(1), 43. <https://doi.org/10.22219/jpbi.v4i1.5476>
- Williams, C. T., Walter, E. M., Henderson, C., & Beach, A. L. (2015). Describing undergraduate STEM teaching practices: a comparison of instructor self-report instruments. *International Journal of STEM Education*, 2(1). <https://doi.org/10.1186/S40594-015-0031-Y>
- Wu, Y.-T., & Anderson, O. R. (2015). Technology-enhanced STEM (science, technology, engineering, and mathematics) education. *Journal of Computers in Education*, 2(3), 245–249. <https://doi.org/10.1007/s40692-015-0041-2>