TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 4, Aralık 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 4, December 2018

http://www.tused.org

The Effect of Conventional Laboratory Practical Manuals on Pre-Service Teachers' Integrated Science Process Skills

Muhammad ADLIM [1], Rusydi NUZULIA[2], Cut NURMALIAH[3]

[1] Prof. Dr., Universitas Syiah Kuala, Darussalam Banda Aceh, Indonesia, ORCID ID: 0000-0001-6278-7775
[2] M.Pd, Universitas Syiah Kuala, Darussalam Banda Aceh, Indonesia
[3] Dr, Universitas Syiah Kuala, Darussalam Banda Aceh, Indonesia

Received: 27.08.2017 **Revised:** 11.10.2018 **Accepted:** 19.12.2018

The original language of article is English (v.15, n.4, December 2018, pp.116-129, doi: 10.12973/tused.10250a)

ABSTRACT

This study explored the effect of conventional laboratory practical manuals on pre-service teachers' integrated science process skills (ISPS). A validated multiple-choice questionnaire with the ISPS components was used to collect data. No significant difference between pre-service subject-specific teachers' (biology, physics and chemistry) ISPS scores was found. The ISPS scores significantly increased along with proliferation in lab practical works, except for physics. Pre-service math teachers, who had no lab practical works, showed significantly higher ISPS scores than pre-service science teachers. The results indicated that all pre-service teachers' ISPS scores fell into intermediate level. Further, it was found that they possessed the lowest scores for such ISPS as identifying and controlling variable, stating operational definition and designing experiments. The common format of the conventional laboratory manual adopted from many universities need to be reformatted for engage learners in all ISPS. To improve learners' ISPS, higher-order thinking assignments should be intensively given to them.

Keywords: assessment, inquiry, science subject, laboratory manual, mathematics

INTRODUCTION

Scientific research processes (i.e., making an observation, proposing a hypothesis, designing a research procedure, analysing data, writing a conclusion and communicating a research finding) develop science. These processes are ideally integrated into school science learning (Anderson, 2002). Students are expected to experience the integrated science process skills (ISPS) through several science courses (Adlim, Samingan & Hasibuan, 2014).

Science process skills (SPS), which play an important role in daily life (Aydogdu, 2015), are widely exploited in other disciplines (Rellero, 1998). These skills are generally associated with such terminologies as higher order thinking, critical thinking, formal reasoning (Monica, 2005; Rezba, et al., 1995; Al-Rabaani, 2014).

Many countries (e.g., Indonesia) have adopted National Science Education Standards (NSES) into their science curricula emphasizing inquiry-based learning. Hence, students are expected to acquire and improve their science process skills (Kimble, Yager & Yager, 2006).

Corresponding author e-mail: adlim@unsyiah.ac.id © ISSN:1304-6020

Indonesia has revised and released its national curriculum in 2013, also some inquiry laboratory manual (Mahyuna, Adlim & Saminan, 2018) and Science Technology Engineering Mathematic (STEM) laboratory module have been studied (Sari, Adlim & A Gani, 2018).

Even though inquiry has been interpreted in different ways, the "Standard" term means much more thing than a science process. That is, it acts as a vehicle for learning science content (Asay & Orgill, 2010). Given inquiry-based learning and the National Science Education Standards (NRC 2000), inquiry learning process consists of five "essential features"; (a) engaging in scientifically oriented questions; (b) giving a priority to evidence in responding to questions; (c) formulating explanations from evidence; (d) connecting explanations to scientific knowledge; and (e) communicating and justifying explanations (NRC 2000, p. 29). Any teacher may direct various essential features through inquiry-based activities (NRC 2000, p. 29). Asay and Orgill (2010), who reviewed the inquiry studies between 1998 and 2007, reported a need for elaboration on how to reformat the laboratory practical manual and how to link it to the SPS. Yildirim, Calik & Ozmen (2016) stated that inquiry-based learning approach acted as a driving factor in developing SPS.

The objective of science curriculum is to design the relevant learning materials/tools, i.e., textbooks, laboratory practical manuals, handouts, and student worksheets. However, very few inquiry-based laboratory manuals have easily been found in open access literatures (AP®, 2015; Grooms, Enderle, Hutner, Sampson, 2016; Flinn Scientific, n.d). Interestingly, most of them have been prepared in a conventional format (including confirmation experiments).

Integrating SPS into laboratory manual seems to have neglected cognitive-knowledge domains. Unfortunately, many teachers have still not fully understood inquiry-based learning reported by Anderson (2002) and Crawford (1999). For this reason, implementing SPS has been problematic for school science learning and teaching in that they are abstract and need much more efforts for planning science courses (Windschitl, 2004). Therefore, the practical implementation in science classes is likely very low (Monica, 2005; Coil et al, 2010; Sukarno, Permanasari, Hamidah, Widodo, 2013), and it will be more complicated in rural schools (Adlim et al, 2014; Ambross, Meiring & Blignaut, 2014).

Although Miller and Driver (1987) argued that SPS are content-related, separating science learning from SPS results in less meaningful learning and memorizing activities. Also, they are unable to demonstrate SPS and acquire an in-depth content knowledge (Monica, 2005).

SPS can be integrated and implemented onto student worksheets of laboratory practical manuals. Thus, exploring their applicability is a crucial for studying SPS. Assessing pre-service teachers' capacities is more significant for preparing and educating them to achieve science process skills and scientific processes for the next generation standards.

Taking complex hierarchical features of science process skills into account, two categories appear: basic science process skills (simple skills) and integrated science process skills (complex, higher-order). Basic science process skills (BSPS) are usually experienced in primary school levels, while integrated science process skills (ISPS) can be accomplished by secondary and high school students (Gurses, Çetinkaya, Dogar, & Sahin, 2015; Delen & Kesercioğlu, 2012). BSPS include several skills in observing, comparing, classifying, measuring, experimenting, predicting and inferring (Tobin & Capie, 1982). ISPS contain identifying/controlling variables, stating hypothesis, designing experiments, graphing/interpreting data and stating operational definition (Dillashow & Okey, 1980; Shahali & Halim, 2010).

Science laboratory practical works are expected to train BSPS and ISPS, since science process skills are a part of lab activities. Another BSPS model also uses computer animations and laboratory virtual works (Yang & Heh, 2007; Supriyatman & Sukarno, 2014). Moreover, using picture books is a successfully method to introduce some science process skills for early childhood education (Monhardt & Monhardt, 2006).

Several studies in SPS have been reviewed. Yildirim et al (2016) reported the profile of SPS implementation in Turkey. Al-Rabaani (2014), who investigated pre-service teachers' SPS (both BSPS and ISPS) levels, reported that their SPS levels of social sciences fell into average level. Further, he implied no significant difference for gender variable at pre-service teachers in Oman. Zedan and Jayosi (2015), who studied with the Palestinian high school students, depicted that female students had higher SPS scores than male ones. Aydogdu (2015), who accessed Turkish science teachers' ISPS, found that they were not at satisfactory level. Karsli, Yaman and Ayas (2010), who sampled Turkish student teachers, addressed that they had difficulty performing SPS-integrated experimental tasks in chemistry laboratories. They also suggested to write SPS-embedded books/worksheets. Similarly, Chabalengula, Mumba and Mbewe (2012) reported that the American pre-teachers' ISPS fell into a moderate level. Downing and Filer (1999) implied that pre-service teachers' science process skills had a positive correlation with their attitudes toward science. Shahali (2015) depicted that Malaysian primary school teachers' understanding of SPS was not as good as their teaching experiences. Although several studies have been reported on the assessment of SPS, how pre-service teachers' ISPS are related to their laboratory practical experiences has been unexplored.

Since the laboratory practical works are conducted by using the conventional science lab manuals then the university usually will face difficulties in improving and accommodating all ISPS. Therefore, worksheets in the laboratory practical manuals need to be analyzed to synchronize pre-service teachers' laboratory work experiences with ISPS. This information will make a great contribution to reformat common science laboratory manuals, student worksheets in laboratory practical manuals and conceptual assignments.

Since ISPS might be drilled during laboratory practical works, then the more students practice the laboratory works, the higher they should have accomplish science process skills. Therefore, this study purposed to explore the ISPS levels of subject-specific pre-service science teachers (chemistry, physics and biology) at different years of the study and compared their levels with those of pre-service math teachers having no science laboratory practices. The current study also intended to explore the content, the frequencies of laboratory practical works, and the students' assignment model and the impact on ISPS.

Research Questions

The following research questions guided the current study:

- Do pre-service teachers' ISPS levels significantly increase along with the proliferation of their lab practical works?
- Do the laboratory practical works significantly affect pre-service science teachers' ISPS levels as compared with those of pre-service mathematics teachers?
- Do pre-service teachers' science syllabuses improve all ISPS?

METHODS

Population and sample

The population of the current study comprised of 813 pre-service teachers enrolled to Semesters III (Admission year was 2015) - V (Admission year was 2014) - VII (Admission year was 2013) in the departments of biology, physics, chemistry and mathematics at Syiah Kuala University, Indonesia. They were distributed to several classes, whose capacities ranged from 24 to 34 students without any academic rank group (homogenous). A total of 360 pre-service teachers (30 x 12); 30 for each semester group (III, V & IV) and for each study program (biology, chemistry, physics and mathematics) was randomly drawn from each department. The flow chart of the current study is summarized in Figure 1.

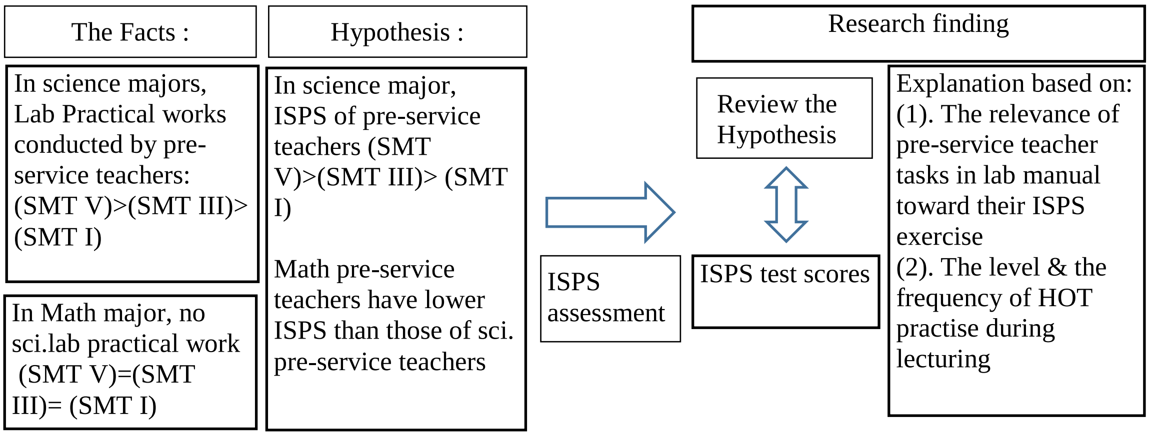

Figure 1. The flow chart of the current study

This study focused on assessing pre-service teachers' ISPS levels and learning experiences. The enrolment test follows national standard with relatively a constant passing grade in each department. The school of education, which has 16 departments, is the oldest institution in Aceh Provinces and one of 374 institutions in Indonesia. Each department runs 4-5 years covering a total of 151 credits, 83% of which are pure science courses. The lecturers dominantly hold master's degree (70-75%), while minority of them has PhD (20%) and Professor (5%) degrees. Their academic backgrounds have highly fallen into mathematics education and pure sciences (biology, chemistry, and physics). A few science educators have been employed in the department. All schools of education in Indonesia follows the same syllabus meeting the national standards. The textbooks and laboratory practical manuals are nearly similar to pure science learning materials for undergraduate programs at worldwide universities (Robson, 2012).

Instrument

A multiple-choice ISPS instrument was adapted from Monica 's (2005) dissertation (see the link at epository.up.ac.za/bitstream/handle/2263/24239/dissertation.pdf;sequence=1) and validated for the current context. In Monica's (2005) study, the items were designed for senior high school students (grades 10-12) and validated with 769 students. Table 1 lists the characteristic of the instrument.

Table 1. *The characteristics of ISPS instrument developed by Monica (2005)*

characteristics of the instrument	Overall	Acceptable (standard) value
Discrimination index	0.403	≥ 0.3
Index of difficulty	0.402	0.4-0.6
Content validity	0.978	≥ 0.7
Reliability	0.810	≥ 0.7
Readability level	70.29	60-70
Reading grade level	Grade 8	$\leq$ grade 9

The original version of the ISPS instrument, which was in English, was administered to South African senior high school students. Then, the researchers translated it from English into Indonesian language. A group of experts (science and math educators) validated its translated version with 30 multiple-choice questions. The content validity was found to be 97.7+0.96. The reliability co-efficient measured by a split-half method was found to be 0.96. The researchers did not measure such other parameters as index difficulty was since the instrument was passed to pre-service teachers, whose academic level was higher than senior high school students. The adapted version of the ISPS instrument is outlined in Table 2.

Table 2. *An outline of indicators in the ISPS instrument*

No.	Indicators	Objectives	Item test number	Total item
1.	Identifying and controlling variables	Describes an investigation, and identifies dependent, independent, control variables	2, 6, 12, 19, 28, 29, 30	7
2.	Operational definition	Describes an investigation, and identifies how variables are operationally defined	1, 7, 22, 23, 26	5
3.	Determining the hypothesis	States a problem with dependent variables and a list of independent variables to identify a testable hypothesis	8, 16, 20	3
4.	Reading graphs and interpreting data	Describes an investigation, obtains results/data, and identifies a graph representing the data	4, 5, 9, 10, 11, 17, 14, 24, 25, 27	10
5.	Designing experiments	Selects a suitable design for test the hypothesis	3, 13, 15, 18, 21	5

Document Analysis and Interview Protocol

The syllabus of each department was analyzed to list the laboratory course works for the laboratory practical manuals. All ISPS was listed and checked to synchronize them with student tasks in the lab practical manuals. The findings were subsequently confirmed by the lab supervisors, lab assistants and several pre-service teachers. Similar procedure was followed for several dominant courses in science and mathematics syllabus to analyze them in regard to the level of Bloom's cognitive taxonomy. Senior science and math lecturers (5 persons) and 10 senior pre-service teachers from each department were interviewed through a structured-interview protocol. That is, senior science and math lecturers listed relevant courses and identified the dominant Bloom levels in their instructions. A similar question list was given to 10 senior pre-service teachers to confirm the lecturers' responses. Finally, their average responses were tabulated.

FINDINGS

Research Question 1*: Do pre-service teachers' ISPS levels significantly increase along with the proliferation of their lab practical works?*

The year of the study determines the seniority in laboratory practical works. That is, pre-service teacher at the third semester was less senior than those at the seventh semester. The more pre-service students spend time in the campus, they have more experience in the laboratory practical works.

Pre-service teachers must annually accomplish 2-3 lab practical courses. If not, they are dropped out from the university. Pre-service teachers under investigation had a good academic achievement (mean of GPA: 3.0).

Even though five ISPS were distributed into 30 multiple-choice items, 4 of them were deleted due to low discrimination index values. 3 of them were revised because of low validity scores. A total` of validated items was 26. However, 20 of them were selected to assess the ISPS, while 6 of them were excluded because of dominant arithmetic calculation. The ISPS items were descriptive, logic and included simple calculation instead of complex one. Mean scores of pre-service science teachers' responses to the ISPS are shown in Table 3.

Table 3. *Mean scores and standard deviation values of pre-service science teachers' responses to the ISPS in regard to the year of the study*

Semesters	Biology		Physics		Chemistry	
	$\bar{x}$ (%)	SD	$\bar{x}$ (%)	SD	$\bar{x}$ (%)	SD
Semester III	57	15	60	11	59	11
Semester V	61	8	60	11	60	10
Semester VII	66	10	63	14	67	14

As seen in Table 3, mean scores of pre-service science teachers' responses to the ISPS ranged from 57 to 67. These range values were categorized under an intermediate level with a large standard deviation. This finding is consistent with previous studies in Oman, Turkey, and USA (Al-Rabaani, 2014; Karsli et al, 2010 & Chabalengula et al, 2012). That is, because pre-service science teachers' ISPS levels are poor, their capacities of the ISPS may influence their science teaching careers in school and prevent their students' perspectives and science learning motivation in future (Aydogdu, 2015; Shahali, 2015).

Before conducting analysis of variance (ANOVA), normality test was counted using chi-square method at significance p = 0.05. This test showed that all was normally distributed with $\chi^2_{calc} < \chi^2_{table}$. No significant difference was found for ISPS levels of subject-specific pre-service teachers(biology, physics and chemistry) at similar semester: $F(90, 2)$ = 0.33; 0.03; 0.80 with, p = 0.71; 0.96; 0.43 respectively. However, a significant difference between semesters at the given subjects, except for physics. That is, these values for biology were $F(30, 2) = 4.3$, $P = 0.02$; while those for chemistry, F (30, 2) =3.6, P = 0.03. There was no significant difference in physics [$F(30, 2) = 0.5$, $p = 0.62$]. It can be deduced that any significant improvement at the ISPS appeared for senior pre-service teachers. This means that experiencing laboratory works is ineffective in evolving all ISPS. However, based on mean scores of pre-service teachers' responses to the ISPS test, dominant fraction of high ISPS scores obviously shifted from less senior (lower semester) to more senior (higher semester) levels for subject-specific pre-service teachers (see Figure 2 a,b,c. For example; the number of pre-service biology teachers' ISPS scores increased along with their lab experience proliferations (Figure 2a). Similar case was observed for pre-service physics teachers (see Figure 2b). That is, their ISPS scores shifted from SMT III (ranging from 26 to 41to SMT V & VII (ranging from 42 to 73) (Figure 2b). Indeed, the highest ISPS score anomaly appeared at SMT III for pre-service physics teachers. The trend was obviously valid for chemistry education program (see Figure 2c). This finding supports Jerome Bruner's learning theory stating that learners actively experience and construct their own knowledge.

Research Question 2*: Do the laboratory practical works significantly affect pre-service science teachers' ISPS levels as compared with those of pre-service mathematics teachers?*

As observed in Figure 3, pre-service teachers' ISPS scores were also analyzed to explore weak and strong components at different subjects and the year of the study.

Consistently, the highest mean score of the ISPS was belonging to “graphing and interpreting data,” whilst the lowest one was pertaining to “designing an experiment”. This finding is in a parallel with previous studies reporting that designing an experiment is very difficult for their samples (Monica, 2005; Aydogdu, 2015; Chabalengula et al, 2012).

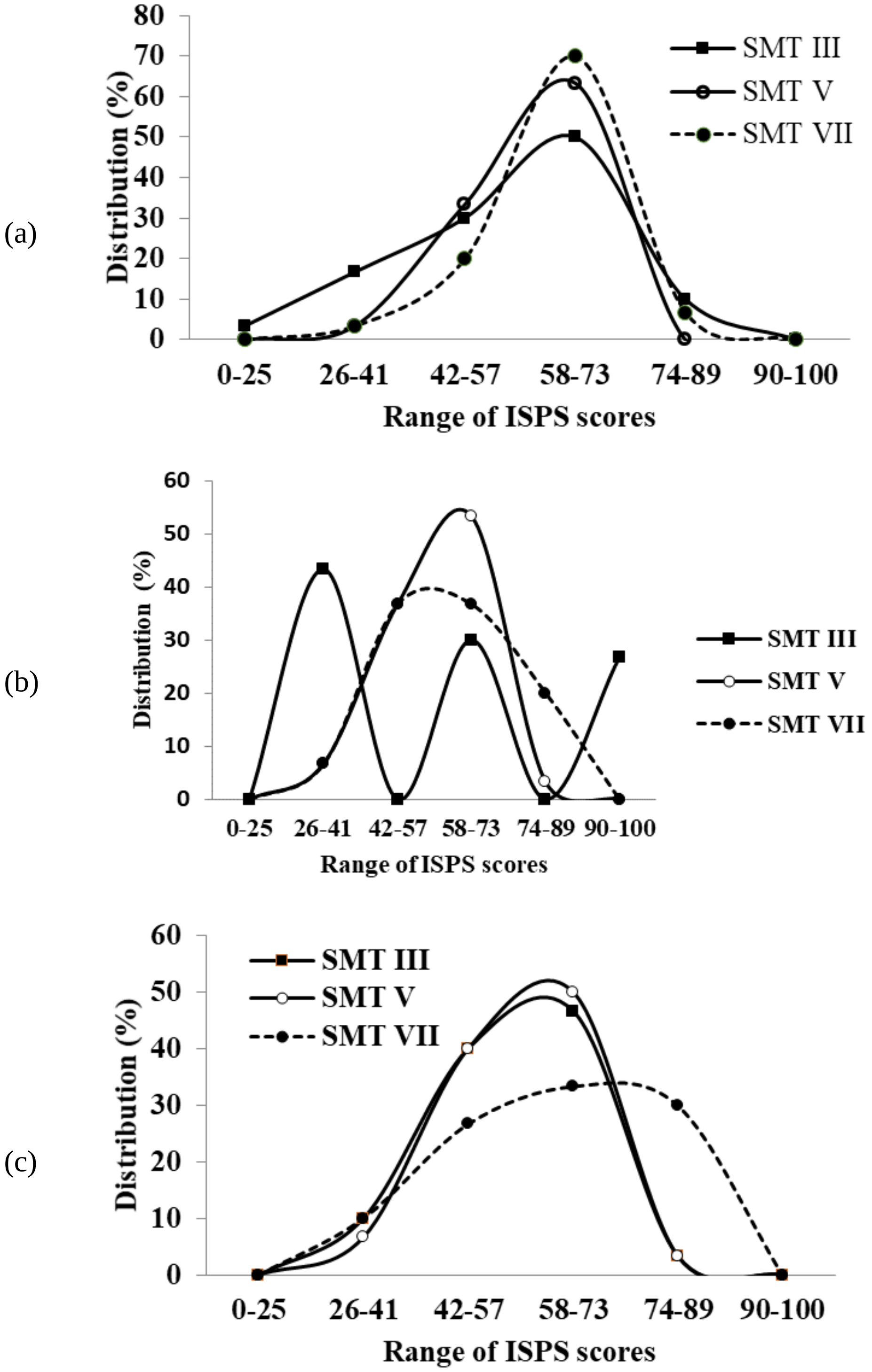

Figure 2. Subject-specific pre-service teacher s’ ISPS scores at different lab practical proliferation (Figure 2a for biology; Figure 2b for physics and Figure 2c for chemistry)

Indeed, the ‘designing an experiment’ skill is a quite complex process incorporating in science process skills, statistical knowledge and systematic thinking skills.

The results indicated that ‘graphing and interpreting data’ skill was the easiest task because it focused on mathematical logic rather than experimental skills. The other ISPS under investigation also required to experience science process skills and higher-order thinking skills.

Lower scores in “Stating Operational Definition”, “Determining the hypothesis” and “Designing an Experiment” skills may result from the present format of the science laboratory practical manuals. That is, since the ISPS under investigation were not found in all lab manuals, pre-service teachers did not experience such skills although taking many laboratory practical works. The pre-service teachers, the head of laboratory and laboratory assistants consistently confirmed this finding.

As seen in Figure 3, pre-service math teachers had higher ISPS scores than pre-service science teachers. This trend appeared at all ISPS and year of the study, except for the ‘Stating Operational Definition’ at Semester III. The ‘designing an experiment’ skill at all semesters was low in all subject-specific pre-service teachers.

The results of ANOVA indicated significant differences between subject-specific pre-service teachers’ ISPS scores at similar semester, except for Semester III. The results of ANOVA for Semesters III, V and VII were F (120, 3) = 1.9, P = 0.13; F(120, 3) = 16, and F(120, 3) = 9.5 respectively.

As can be seen from Figure 3, the ISPS is independent on the laboratory practical works since pre-service math teachers, who did not have any laboratory practical work/manual, had the highest ISPS scores. This may come from the features of mathematics activities or learning, i.e., problem solving, reasoning ability and high order thinking skills.

Problem solving activities involve cognitive processes underpinning conceptual and procedural understanding. Conceptual understanding is developed based on interpretation of the facts, whereas the procedural understanding is drilled with exercise skills (Gott & Duggan, 1995).

Higher order thinking (HOT) skills, which are congruent with the ISPS, commonly practice mathematic learning through the ISPS (Tajudin, 2015). Students, who are good at HOT, usually have capacity to manipulate information and idea to synthesize, generalize, explain, formulate hypothesis, or reach some conclusions or interpret a given case. By mastering the systematic thinking skills, they are able to solve problem and discover new meanings or understanding. Some of mathematic assignments requesting to conduct any scientific investigation might also build the ISPS. For example; “*please design a pool, whose area is 24* m^2*, and provide several alternative shapes that allow costumer to choose the options, compare their costs of the surrounding areas*”. To solve this problem, the pre-service teachers need to determine the variables affecting the operational costs and define the hypothesis. Because of designing an experiment or simulation to reject or accept the hypothesis, such a process may have contained and evolved all ISPS.

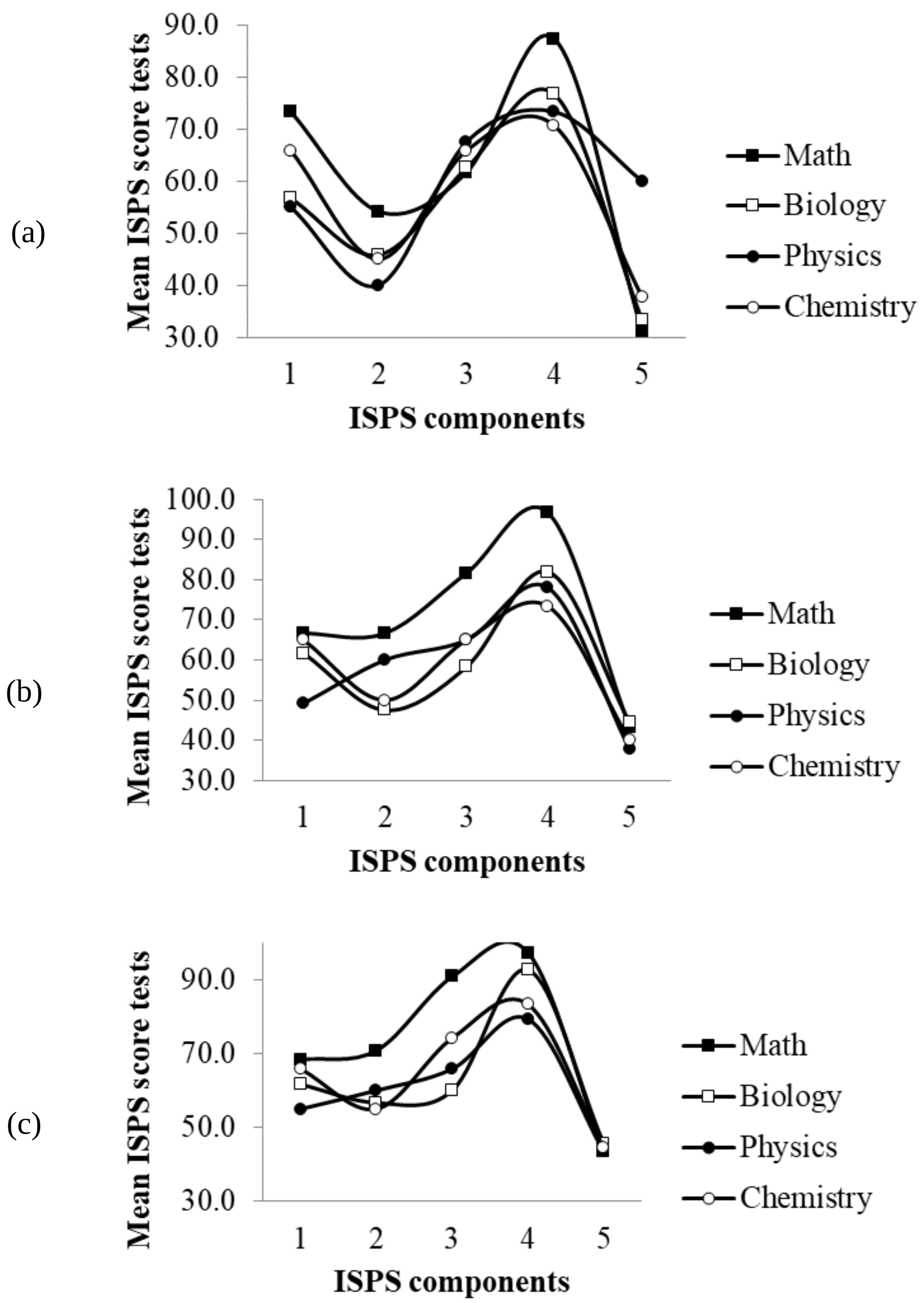

Figure 3. Mean scores of subject-specific pre-service teachers' ISPS ;
(a) Semester III, (b) Semester V, (c) Semester VII;
Coordinate legend:
(1) *Identifying an controlling variables;* (2) *Stating operational definition*
(3) *Determining the hypothesis;* (4) *Graphing and interpreting data*
(5) *Designing an Experiment*

To compare pre-service science teachers' HOT with those of pre-service mathematics teachers, the researchers conducted structured interview protocols with 5 lectures and 10 senior pre-service teachers, as representatives for each teacher education program. By randomly sampling 10 courses in each teacher education program, the interviewees were asked to check the dominant courses in regard to Bloom's taxonomy. As shown in Figure 4, mathematics courses included their learning activities within C3-C5 of cognitive domain as compared with science courses. This confirmed that pre-service math teachers had frequently practiced with HOT, which fell into C3-C5 of thinking levels. The logic, reason and systematic thinking may have affected to any improvement in the ISPS scores.

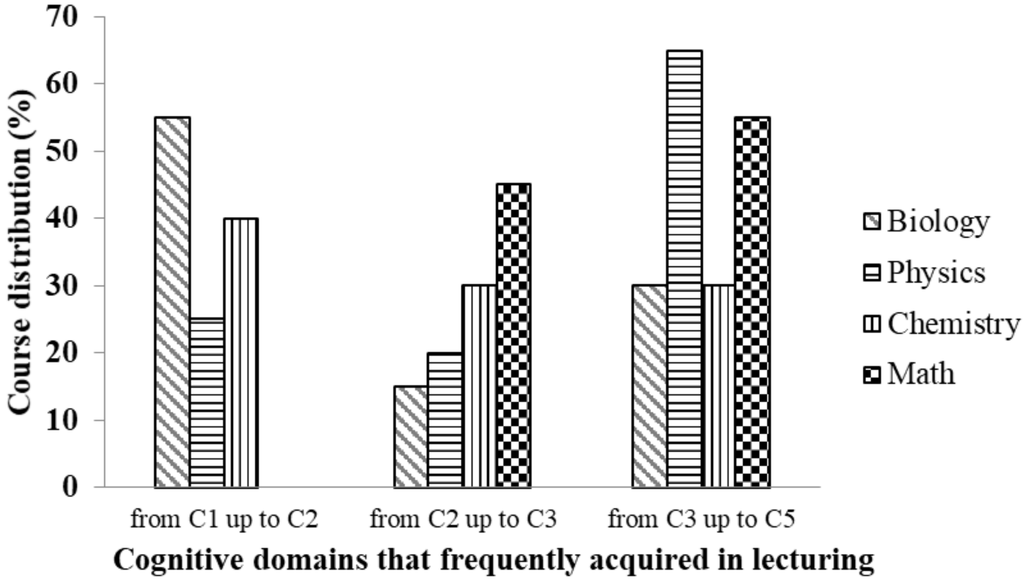

Figure 4. Pre-service teachers' cognitive domains of science and mathematics courses.

Research Question 3: *Do pre-service teachers' science syllabuses improve all ISPS*?

Even though syllabus has a broad meaning, this study specified science syllabus as the laboratory activities in the laboratory practical manuals. Table 4 presents the number of laboratory practical manuals for each subject in syllabi of teacher training program. The contents of lab manuals were reviewed and matched with the ISPS. It was found that the manual format composed of title of experiment, theory, material and procedure (structured tables for students) and questions.

Three head of laboratories and 15 pre-service teachers as representatives for each subject-specific pre-service teachers were interviewed to verify the ISPS presentation in the manuals. The interview data revealed that the ISPS were not found in the manuals, except for data analysis and graphing (see Table 4).

Table 4. *Subject-specific pre-service science teachers' syllabuses*

Disciplines	Laboratory Practices (total numbers)		Frequencies of the ISPS explicitly found in the lab manuals				
	Credit hours	Lab. manuals	Indetify. &control. variables	Stating operat. definition.	Deter-mining hypo-thesis	Graphing & interpret. data	Designing experiment
Biology	17	17	none	none	none	always	none
Physics	12	9	none	none	none	always	none
Chemistry	17	13	none	none	none	always	none

The format of the lab practical manuals for each subject was almost similar to those of other well-known universities. Science lab manuals from Durham University, Reed College, Austin College, Massachusetts Institute of Technology and 9 others partially contained the ISPS (Ronson, 2012; "lab reference, n.d" ; 1406manualRRC, n.d & Physics 123, n.d). The experimental procedures were represented in detail. Also, there was no task for students to state their hypothesis, find the variables and design the experiments (Gobaw, 2016; Tweedy & Hoese, 2005; Basey, Mendelow & Ramos, 2000; Germann, Haskins & Auls, 1996). Biology lab manuals (as a typical format of a lab practical manual) at University of Illinois and University of Maryland, USA contained almost all ISPS (AP® Biology, n.d; Experiment MF, n.d). These manuals, which provided the research questions, asked the students to write their hypothesis, design the experimental procedure, analyze data and write their reports. By doing this, the students may have acquired 'designing experimental procedures, operational definition and identifying variables' skills of the ISPS.

DISCUSSION and CONCLUSION

Most of the conventional laboratory practical manuals contained confirmative experimental works, "alike cookbook". They did not give any chance for students to practice their ISPS, especially "controlling variable" and "designing an experiment" skills. Doing many laboratory practices does not build all ISPS unless the laboratory practical manuals are designed for building the ISPS. The research finding showed that pre-service teachers found difficulty in identifying and controlling variables, stating operational definition, determining a hypothesis and designing an experiment, which are ISPS components. Conventional laboratory manuals may improve "graphing and interpreting data" skill. Doing frequent exercises in problem solving and HOT may evolve the ISPS. Overall, because the conventional laboratory practical manuals had difficulties improving almost all of ISPS, a new format involving in all ISPS need to be developed. Also, this new format should engage students in several assignments containing higher order thinking, problem solving and research questions, tasks and student worksheets.

Suggestions

The participants of this study were undergraduate students which is known as pre-service teachers at a teacher training school. Fur further study, it is interesting to compare their ISPS with the ISPS of in-service teacher and the ISPS of other undergradaute students having major in pure science and engineering. Disparity might be considered because the in-service teachers have more experience in science teaching and the pure scince and engineering students have more science credit hours in their curriculum.

REFERENCES

Adlim, M., Samingan, & Hasibuan, R. A (2014). Integrating entrepreneurial practice in contextual learning of biotechnology for senior high school students, *Journal of Turkish Science Education, 11(2)*, 111-122.

Adlim, M., Soewarno, S., Khairil, Usman, Hasbi, Hasmunir, Armia, Ishak & Yasin, B. (2014). Assessing chemistry-learning competencies of students in isolated rural senior high schools by using the national examination: a case study of Simeulue island, Indonesia. *International Journal of Science and Mathematics Education, 12*, 817-839. doi: 10.1007/s10763-013-9440-x.

Al-Rabaani, A. (2014). The acquisition of science process skills by Omani's pre-service social studies' teachers. *European Journal of Educational Studies, 6 (1)*, 13-19. doi:10.18767/ejes.25482.

Ambross, J., Meiring, L., & Blignaut, S. (2014). The implementation and development of science process skills in the natural sciences: A case study of teachers' perceptions, *Africa Education Review, 11(3)*, 459-474. doi: 10.1080/18146627.2014.934998.

Anderson, R. D. (2002). Reforming science teaching: what research says about inquiry. *Journal of Science Teacher Education*, *13(1)*, 1–12. doi: 10.1023/A:1015171124982.

AP® (2015). AP-Physic Inquiry Laboratory manual. https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-physics-inquiry-based-lab-manual.pdf, July 29, 2017.

AP® Biology investigative lab: An Inquiry-Based Approach (n.d) retrieved from http://www.collegeboard.com/html/apcourseaudit/courses/pdfs/cb-biology-lab-manual-1-24-12.pdf, April 29, 2017.

Asay, L. D., & Orgill, M. (2009). Analysis of essential features of inquiry found in articles published in the science teacher, 1998-2007. *Journal of Science Teacher Education, 21(1)*, 57-79. doi:10.1007/s10972-009-9152-9.

Aydogdu, B. (2015). The investigation of science process skills of science teachers in terms of some variables. *Education Research and Reviews, 10(5),* 582-594. doi: 10.5897/ERR2015.2097.

Basey, J. M., Mendelow, T. N., & Ramos, C. N. (2000). Current trends of community college lab curricula in biology: an analysis of inquiry, technology, and content. *Journal of Biological Education, 34 (2),* 80-86. doi: 10.1080/00219266.2000.9655690.

Chabalengula, V.M., Mumba, F., & Mbewe, S. (2012). How pre-service teachers' understand and perform science process skills. *Eurasia Journal of Mathematics, Science & Technology Education, 8(3)*, 167-176. doi: 10.12973/eurasia.2012.832a.

Coil, D., Wenderoth, M. P., Clarissa Dirks, C., & Cunningham, M. (2010). Teaching the process of science: faculty perceptions and an effective methodology. *CBE—Life Sciences Education, 9*, 524–535. doi: 10.1187/cbe.10-01-0005. PMCID: PMC2995770.

Crawford, B. A. (1999). Is it realistic to expect a preservice teacher to create an inquiry-based classroom? *Journal of Science Teacher Education, 10(3),* 175-194. doi:10.1023/A:1009422728845.

Dillashaw, F. G., & Okey, J. R. (1980). Test of integrated science proses skills for secondary students. *Science Education, 64*, 601-608. doi: 10.1002/sce.3730640506.

Delen, I., & Kesercioğlu, T (2012). How Middle School Students' Science Process Skills Affected by Turkey's National Curriculum Change? *Journal of Turkish Science Education 9(4)*:3-9.

Downing, J. E., & Filer, J.D. (1999). Science process skills and attitudes of preservice elementary teachers. *Journal of Elementary Science Education, 11 (2)*: 57-64. doi:10.1007/BF03173838.

Experiment MF—Magnetic Force, (n.d) retrieved from https://ocw.mit.edu/courses/physics/8-02x-physics-ii-electricity-magnetism-with-an-experimental-focus-spring-2005/labs/experiment_mf.pdf, April 29, 2017.

Flinn Scientific Advanced Inquiry Labs for AP* Chemistry Lab Manual https://www.flinnsci.com/flinn-scientific-advanced-inquiry-labs-for-ap-chemistry-lab-manual/ap7671/#variantDetails, July 29, 2017.

Germann, P. J., Haskins, S., & Auls, S. (1996). Analysis of nine high school biology laboratory manuals: promoting scientific inquiry. *Journal of Research in Science Teaching, 33(5),* 475-499. doi: 10.1002/(SICI)1098-36(199605)33:5<475::AID-TEA2>3.0.CO;2-O.

Gobaw, G. F. (2016). Analysis of undergraduate biology laboratory manuals. *International Journal of Biology Education, 5(1),* 34-49. doi: 10.20876/ijobed.99404.

Gott, R., & Duggan, S (1965). *Investigative Work in the Science Curriculum*, Buckingham: Open University Press.

Grooms, J., Enderle, P. J., Hutner, T., & Sampson, V (2016). *Student Lab Manual for Argument-Driven Inquiry in Physical Science: Lab Investigations for Grades* 6-8. https://www.nsta.org/store/product_detail.aspx?id=10.2505/9781681405261.

Gürses, A., Çetinkaya, S., Dogar, C., & Sahin, E. (2015). Determination of levels of use of basic process skills of high, school students, *Procedia - Social and Behavioral Sciences, 191*, 644 – 650. doi: 10.1016/j.sbspro.2015.04.243.

Karsli, F., Yaman, F., & Ayas, A. (2010). Prospective chemistry teachers' competency of evaluation of chemical experiments in terms of science process skills. *Procedia Social and Behavioral Sciences, 2*, 778-781. doi: 10.1016/j.sbspro.2010.03.101.

Kimble L. L., Yager, R. E., & Yager, S. O. (2006). Success of a professional-development model in assisting teachers to change their teaching to match the more emphasis conditions urged in the national science education standards. *Journal of Science Teacher Education, 17(3)*, 309-322. doi: 10.1007/s10972-006-9022-7.

Laboratory reference manual, (n.d) retrieved from http://www.reed.edu/chemistry/alan/201_202/lab_manual/, April 29, 2017. 1406manualRRC, n.d retrieved from https://drive.google.com/file/d/0BxZ7UnOPp6OVU29pWkVhUTlILVE/view, April 29, 2017

Millar, R., & Driver, R. (1987). Beyond processes. *Studies in Science Education, 14*, 33-62. doi: 10.1080/03057268708559938.

Monhardt, L., & Monhardt, R. (2006). Creating a context for the learning of science process skills through picture books. *Early Childhood Education Journal, 34 (1)*, 67-71. doi: 10.1007/s10643-006-0108-9.

Mahyuna, M., Adlim, M., & Saminan, I (2018). Developing guided-inquiry-student worksheets to improve the science process skills of high school students on the heat concept, *Journal of Physics: Conference Series*, 1088, 012114.

Monica, K. M. M. (2005). Development and validation of a test of integrated science process skills for the further education and training learners (*Master Dissertation*) retrieved from : http://repository.up.ac.za/bitstream/handle/2263/24239/dissertation.pdf;sequence=1, April 29, 2017.

National Research Council (NRC). (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Rellero, P. (1998). Process skill and content knowledge. *Science Activities: Classroom Projects and Curriculum Idea*, 35(3):3-4. doi: 10.1080/00368129809600910.

Rezba, R. J., Sparague, C. S., Fiel, R. L., Funk, H. J., Okey, J. R., & Jaus, H. H. (1995). *Learning and Assessing Science Processes* (3rd Ed). Kendall: Publishing Company.

Robson, J. (2012). *First Year Undergraduate Chemistry Laboratory Course Manual 2011-2012, core chemistry*, retrieved from http://www.rsc.org/learn-chemistry/resource/res00000963/ first-year-undergraduate-chemistry-laboratory-course-manual-2011-2012, April 29, 2017.

Sari, R. P., Adlim, M., & Gani, A. (2018). STEM learning in regular and vocational high schools on the topic of scientific menu card fabrication, *Journal of Physics: Conference Series, 1088*, 012114.

Shahali, E. H. M., & Halim, L. (2010). Development and validation of a test of integrated science process skills. *Procedia Social and Behavioral Sciences, 9*, 142–146. doi: 10.1016/j.sbspro.2010.12.127.

Sukarno, Permanasari, A., Hamidah, I., & Widodo, A. (2013). The analysis of science teacher barriers in implementing of science process skills (sps) teaching approach at junior high school and it's solutions. *Journal of Education and Practice, 4(27)*, 185-190.

Supriyatman & Sukarno (2014). Improving science process skills (sps) science, concepts mastery (scm) prospective student teachers through inquiry learning instruction model by using interactive computer simulation. *International Journal of Science and Research, 3(2),* 6-9.

Tajudin, N. M. (2015). Mathematical knowledge and higher order thinking skills for teaching algebraic problem solving, In F. Uslu (ed.), *Proceedings of SOCIOINT15-2nd, International Conference on Education, Social Sciences and Humanities. Istanbul,* Turkey (pp. 26-35). Istanbul, Turkey: OCERINT.

Tobin, K. G., & Capie, W. (1982). Development and validation of a group test of integrated science process skills. *Journal of Research in Science Teaching, 19(2),* 133-141. doi: 10.1002/tea.3660190205.

Tweedy, M. E., & Hoese, W. J. (2005). Diffusion activities in college laboratory manuals. *Journal of Biological Education, 39(4),* 150-155. doi: 10.1080/00219266.2005.9655988.

Windschitl, M. (2004). Folk theories of ?inquiry:? How preservice teachers reproduce the discourse and practices of a theoretical scientific method. *Journal of Research in Science Teaching, 41(5),* 481-512. doi:10.1002/tea.20010.

Yang, K.Y., & Jia-Sheng Heh, J. S. (2007). The impact of internet virtual physics laboratory instruction on the achievement in physics, science process skills and computer attitudes of 10th-grade students, *Journal of Science Education Technology, 16,* 451–461. doi: 10.1007/s10956-007-9062-6.

Yildirim, M., Calik, M., & Ozmen, H. (2016). A Meta-Synthesis of Turkish Studies in Science Process Skills, *International Journal of Environmental & Science Education, 11 (14)* 6518-6539.

Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among Palestinian secondary school students. *World Journal of Education, 5 (1),* 13-24. doi: 10.5430/wje.v5n1p13.