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PRESERVICE CHEMISTRY TEACHERS' CHEMICAL LITERACY BASED ON PISA AND TIMSS RESULTS FOR INTERNATIONAL AND INDONESIAN STUDENTS

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ABSTRACT

PISA and TIMSS results have been used as a basis for educational reform, but unfortunately, teachers' understanding of PISA and TIMSS tests is rarely investigated. We evaluated 149 sophomore preservice chemistry teachers' achievement in TIMSS and PISA-like test. As a way to reflect on TIMSS and PISA results, we compared preservice chemistry teachers' achievement to PISA and TIMSS results for Indonesia and the international students. Results suggested that, to a certain degree, preservice chemistry teachers have a better chemical literacy than Indonesian students and a somewhat similar chemical literacy with international students.

Keywords: preservice chemistry teachers; chemical literacy; PISA; TIMSS

ABSTRAK

Hasil PISA dan TIMSS telah digunakan sebagai dasar reformasi pendidikan tetapi sayangnya pemahaman guru tentang tes PISA maupun TIMSS jarang diselidiki. Kami mengevaluasi pencapaian 149 calon guru kimia tingkat pertama dalam tes semacam PISA maupun TIMSS. Untuk merefleksikan hasil TIMSS dan PISA, kami juga membandingkan pencapaian calon guru kimia dengan hasil PISA dan TIMSS untuk siswa Indonesia dan internasional. Hasil menunjukkan bahwa sampai tingkat tertentu, calon guru kimia memiliki kemampuan literasi kimia yang lebih baik dibandingkan siswa Indonesia dan literasi kimia yang hampir setara dengan siswa internasional.

Kata kunci: calon guru kimia; literasi kimia; PISA; TIMSS

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INTRODUCTION

Evaluation is a process for determining if learning experiences resulted in the desired results (Tyler, 2013). For more than two decades, Trends in International Mathematics and Science Studies (TIMSS) launched in 1995 by International Association for the Evaluation of Educational Achievement (IEA) and Programme for International Student Assessment (PISA) initiated in 1997 by Organization for Economic Cooperation and Development (OECD) has been evaluating students' learning achievement across countries (Martin, Mullis, Foy, and Stanco,2012;OECD,2016). TIMSS evaluates fourth and eighth-grade students' mathematics and science achievement (Martin et al., 2012) while PISA assesses mathematics, reading, and science literacy in 15 years old students (OECD, 2016). Both evaluation aimed to provide insight on how educational system are functioning and as a scientific groundwork for educational improvement.

TIMSS and PISA evaluation (Martin et al., 2012; OECD, 2016) evaluated students' science achievement in which PISA views skills required to engage in reasoned discourse about science related issues as science literacy. Scientific literacy emphasizes scientific ways of knowing and the process of thinking critically and creatively about the natural world (Maienschein et al., 1998) in which a scientifically literate person possesses competencies to explain phenomena scientifically, evaluate and design scientific inquiry, as well as interpret data and evidence scientifically (OECD, 2016). In interpreting PISA and TIMSS results, Wu (2009) suggested that educators should interpret at item level to gain more information about knowledge or skills results in particular countries. TIMSS and PISA classified science achievement according to major science fields (Biology, Chem-

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istry, Physics, and Earth science), and for approximately 26% of countries including Indonesia, science subject with the lowest average score was chemistry (Martin et al., 2012, Exhibit 3.2). In chemistry, scientific literacy is called as chemical literacy to address the particular aspects of chemistry domain (Shwartz, Ben-Zvi, and Hofstein, 2006; Gilbert and Treagust, 2009).

TIMSS and PISA results have been used as a basis for educational reform in many countries such as Finland (Rautalin and Alasuutari, 2007, 2009; Lavonen and Laaksonen, 2009), Denmark (Andersen, 2010; Dolin and Krogh, 2010), Spain (Perelman and Santin, 2011), Turkey (Gur, Celik, and Ozoglu, 2012), as well as Latvia, Estonia, and Russia (Carnoy, Khavenson, and Ivanova, 2015), mainly in the form of curriculum reform. Gur et al. (2012) argued that curriculum reform itself would be insufficient for achieving a quality educational system if factors determining the quality of education, such as teachers' quality, are overlooked. Several studies have put forth the problems in preservice or inservice teacher quality, for example, the quality of science teachers (Kind, 2014; Sujana, Permanasari, Sopandi, and Muzakir, 2014; Barnhart and van Es, 2015; Kang and Anderson, 2015; Fakhriyah, Masfuah, Roysa, Rusilowati, and Rahayu, 2017). Science teachers' quality is a particular area of concern because experts suggested that science teacher quality reflected students results in TIMSS or PISA (Holliday and Holliday, 2003; Vlaardingerbroek and Taylor, 2003; Akiba, LeTendre, and Scribner, 2007; Lavonen and Laaksonen, 2009; Pinto and El Boudamoussi, 2009; Beese and Liang, 2010; Knipprath, 2010).

In terms of Chemistry and teacher quality, previous studies revealed that preservice chemistry teacher's understanding of science-related concepts such as environmental (Robinson and Crowther, 2001) and physical properties of a substance (Gultepe, 2016) still considered as inadequate. Cengiz and Karataz (2015) showed that preservice chemistry students' achievement in the general chemistry laboratory was poor, and their functional and multi-dimensional chemical literacy were insufficient (Celik, 2014). The study focusing on preservice science teachers, especially preservice chemistry teacher's understanding of or their ability in PISA or TIMSS, is currently scarce in the literature. Therefore, we evaluated preservice chemistry teachers' achievement in TIMSS and PISA-like test. As a way to reflect on TIMSS and PISA, we also compared preservice chemistry teachers' achievement with TIMSS and PISA results for Indonesian and international students.

METHOD

With a cluster random sampling technique, we sampled 149 sophomore preservice chemistry teachers from four state universities in Aceh Province, Indonesia (51, 43, 29, and 26 students from each university). To evaluate preservice chemistry teachers' achievement, we compiled test items containing chemistry content based on PISA and TIMSS released test items and translated it into Bahasa Indonesia. Translation validity and readability were evaluated, and we made several adjustments in word choices that the students might found confusing, such as soot, emission, and constant. We classified preservice teachers' achievement in chemistry based on content, process, and context (PISA) and in content and cognitive domain (TIMSS), in which we will henceforth address it as chemical literacy to elucidate the specificity (Shwartz et al., 2006; Gilbert and Treagust, 2009). PISA and TIMSS-like test answers were descriptively processed as proportion correct (correct answers divided by total questions). Chemical literacy differences between PISA and TIMSS results for Indonesian students and the International students were tested statistically with Anova in SPSS 21 version.

RESULTS AND DISCUSSION

Compared to Indonesian students PISA results, preservice chemistry teachers' outperformed Indonesian students in understanding composition, properties and chemical changes of matter but achieved lower scores for energy and its transformation subtest (Figure 1a). For science process (Figure 1b), preservice teachers outperformed Indonesian students in all subtests. Preservice chemistry teachers also have a better grasp of the use of chemistry in issues related to the environment, hazard, and natural resources but an inferior ability in understanding the use of chemistry as the frontiers of science, technology, and health (Figure 1c). Difference between preservice chemistry teachers and Indonesian students achievement was statistically insignificant (p=0.348, Table 1) because even though preservice chemistry teachers in our study have a better understanding and skills in several aspects, their understanding of energy

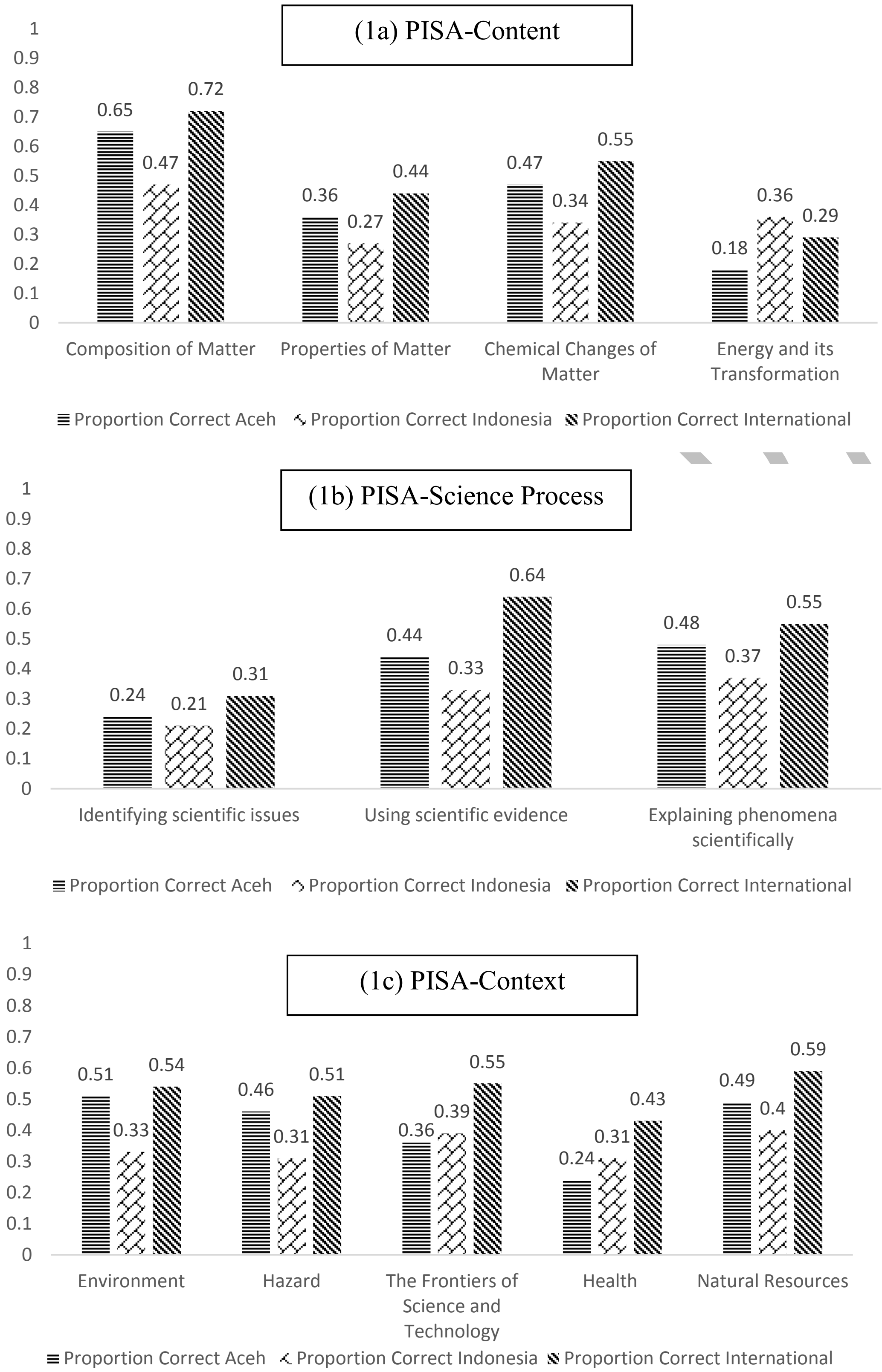
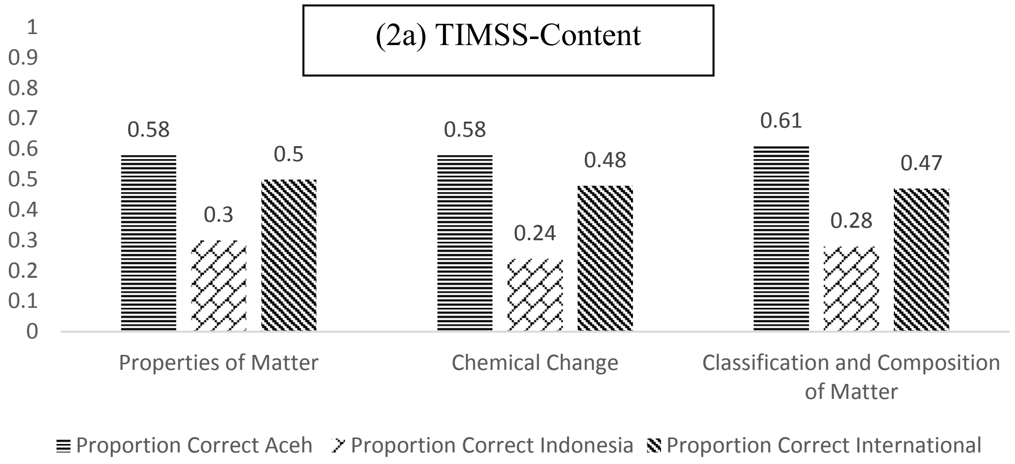


Figure 1a-c. Preservice Chemistry Teachers, Indonesian, and International Students Achievement Results in Content (1a), Science Process (1b), and Context (1c).



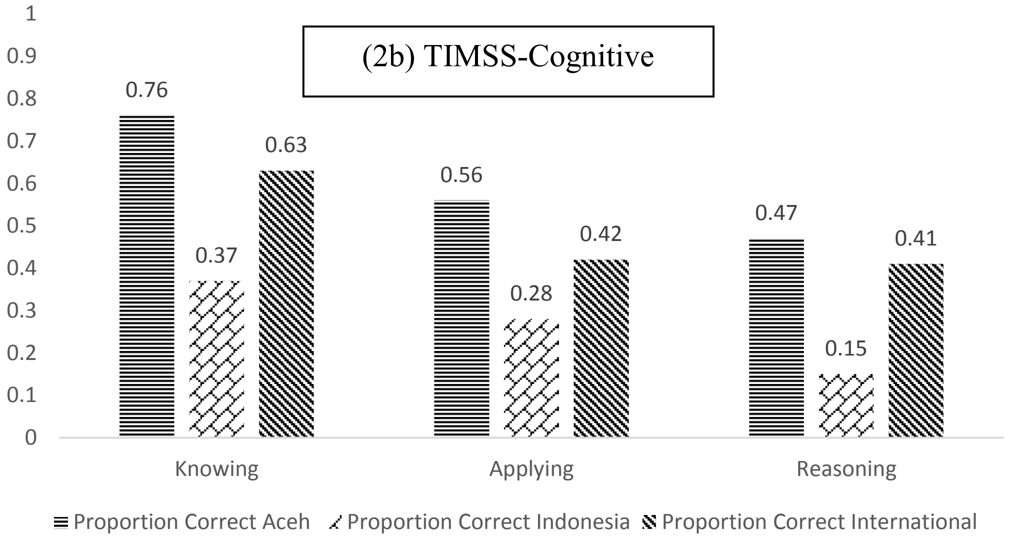


Figure 2a-b. Preservice Chemistry Teachers, Indonesian, and International Students Achievement results in Content (2a) and Cognitive Domain (2b).

Table 1. Statistical Analysis for Preservice Chemistry Teachers, Indonesian, and International Students Achievement Results Difference

Type of Evaluation	**Data Normality and Homogeneity**	**Anova**	**Tukey's Post Hoc**
PISA	Normal (p=0.200) and homogenous (p=0.071 for pre service chemistry teachers)	Significant (p= 0.042)	Significant for difference between Indonesian and international students (p= 0.033). Insignificant between pre service chemistry teachers and Indonesian students (p=0.348) or between pre service chemistry teachers and International students (p=0.449).
TIMSS	Normal (p=0.200; 0.083; 0.200) and homogenous (p=0.780 for pre service chemistry teachers)	Significant (p= 0.04)	Significant for difference between pre service chemistry teachers and Indonesian students (p= 0.04). Insignificant between pre service chemistry teachers and international students (p=0.465) or between international and Indonesian students (p=0.068).

and its transformation as well as the use of chemistry as the the frontiers of science, technology, and health was inferior to Indonesian students. Compared to International students' PISA results, preservice chemistry teachers achieve inferior results in all content, science process, and context aspects. However, the difference was statistically insignificant (p=0.449) because international students could only outperformed preservice chemistry teachers in a relatively narrow margin (Figure 1a-c).

PISA-like test findings suggested that although preservice teachers have a somewhat better understanding and skills in several chemical literacy aspects, their understanding of energy and its transformation as well as the use of chemistry as the the frontiers of science, technology, and health was still insufficient. These results also indicated that preservice chemistry teachers still have an inadequate understanding of complex issues or concepts in chemistry. In a similar vein, Celik (2014) found that preservice science teachers have deficient levels of functional and multidimensional chemical literacy in which the teachers were less literate in multidimensional chemical issues. Concerning particular issue in energy and its transformation, previous studies (Azizoglu, Alkan, and Geban, 2006; Kind, 2013; Gultepe, 2016) corroborated preservice chemistry students' lack of understanding in thermochemistry. In Kind (2013) study, preservice teachers with physics as educational background even outperformed preservice science teachers with a chemist educational background in a mole concept. Failure in understanding such basic concepts can resulted in difficulties in understanding more complex concepts.

TIMSS-like test result showed that preservice chemistry teachers outperformed both Indonesian and international students, but the average score difference was significant between preservice and Indonesian students (p=0.04) and insignificant (p=0.465) with international students. A significant difference was found between preservice chemistry teachers and Indonesian students because preservice chemistry teachers' average score nearly double that of Indonesian students (Figure 2a-b). On the contrary, the average difference between preservice chemistry teachers with international students was only around 0.10-0.12 points, and therefore, preservice chemistry teachers only dismally outperformed international students.

Several studies have previously suggested teacher quality indicates students results in TIMSS or PISA (Holliday and Holliday, 2003; Vlaardingerbroek and Taylor, 2003; Akiba et al., 2007; Lavonen and Laaksonen, 2009; Pinto and El Boudamoussi, 2009; Beese and Liang, 2010; Knipprath, 2010). Reflecting from PISA and TIMSS-like results in preservice chemistry teachers, it can be inferred that to a certain degree, preservice chemistry teachers have a better chemical literacy than Indonesian students and a somewhat similar chemical literacy with international students. The next question that entailed is, will they be able to be a good chemistry teacher for their students if they only have a slightly better chemical literacy than their supposed students?.

Continuously eliciting, attending, interpreting, and responding to student thinking and understanding are traits of a responsive teacher (Kang and Anderson, 2015). To be able to probe student's understanding, teachers should have a complete understanding of subject matter knowledge. Van Driel, De Jong, and Verloop (2002) stated that preservice teachers' ability to transforms subject matter knowledge into a more accessible form for learners depends on their subject matter knowledge and it unfortunately often contains deficiencies. As studies proved that preservice chemistry students' knowledge deficiencies could be remediated (Cidgemoglu and Geban, 2016; Cidgemoglu, Arslan, and Cam, 2017), subjecting preservice teacher to improvement program such as specific field-based activities, workshops on scientific articles, and mentorship could improve their pedagogical content knowledge (Van Driel et al., 2002). Preservice chemistry teachers in our study were still in their sophomore year, so that they still have at least three years to improve their competencies as future chemistry teachers. There still adequate time to upgrade their capacity, and the findings can be used as a reference to compose an informed educational ground plan. In addition to on their own hands, enhancing their competencies is the duty of preservice teachers' educators.

Our sample study was still limited, and we are also aware of the limitation of PISA or TIMSS data (Bracey, 2000; Holliday and Holliday, 2003; Wagemaker, 2008; Rutkowski and Rutkowski, 2016; Jailani and Wulandari, 2017) but our findings can be considered as small steps ahead in the long term and continuous efforts to improve preservice chemistry education program.

CONCLUSIONS

PISA-like test findings suggested that preservice teachers understanding of energy and its transformation as well as the use of chemistry as the frontiers of science, technology, and health was still insufficient. TIMSS-like test result suggested that preservice chemistry teachers' significantly outperformed Indonesian students but only narrowly and insignificantly outperformed international students. Collectively, to a certain degree, preservice chemistry teachers have a better chemical literacy than Indonesian students and a somewhat similar chemical literacy with international students.

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