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Pre-Service Chemistry Teachers' Competencies in Laboratory: A Cross-Grade Study in Solution Preparation

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Abstract: One of the prerequisites for chemistry teacher candidates is to demonstrate certain laboratory skills. This article aims to determine and discuss the competencies of pre-service chemistry teachers in a chemistry laboratory context working with solution chemistry content. The participants in this study consisted of a group of pre-service chemistry teachers in the first to fifth years of a chemistry teacher education program. The participants were given individual tasks of preparing solutions of a certain concentration. The task included two steps: calculation and application. The participants were also observed in terms of the degree to which they followed the laboratory safety rules. Overall, the pre-service teachers made numerous errors in calculating the correct amounts of a substance and preparing a solution, as well as obeying the safety rules. Interestingly, the participants' laboratory competencies showed a trend along their grade levels; namely, a slight increase and then a sharp decrease in their solution preparation knowledge and skills that could be associated with retention loss or decay over time in absence of rehearsal and/or ill-encoding. These results may contribute to the discussion on virtual and physical laboratories in chemistry education.

Key words: chemistry education, cross-grade, problem solving, solution chemistry, teacher training

Introduction

The main investigation field of chemistry involves atom, ions, molecules, interactions among these entities and forces that govern atomic and molecular level. Therefore, topics in chemistry education include abstract atomic level or symbolic representations at both secondary and tertiary level (Ayas & Demirbaş, 1997; Nakhleh, 1992). Even though there are few opponents (Hawkes, 2004), many claim that chemistry laboratories for chemistry education are crucial learning environments for very abstract nature of chemistry topics (Singer, Hilton, & Schweingruber, 2006; Zoller & Pushkin, 2007). Inquiry based teaching has been addressed by the US and other nations' calls for reform in science education and placed as a major goal for science education standards (NAP, 2013). Chemistry laboratory has been proposed as one of the main components of inquiry based teaching. In essence, students can act as researchers in laboratories and learn science process skills by naturally observing, measuring, inferring, controlling variables, experimenting, etc. (Basağa, Geban, & Tekkaya, 1994). Laboratories in chemistry education are considered to have potential to a crucial medium not only for improving science process skills, but also conceptual understanding by making abstract subjects more concrete and visual (Ayas, Çepni, & Akdeniz, 1994; Bybee, 2000; Laredo, 2013). Similarly Hofstein and Lunetta (2004) noted that the primary emphasis of laboratories would not be limited to learning certain scientific methods or laboratory techniques, but rather laboratories should allow students to investigate phenomena by using the methods and procedures of science and solve problems. Research in this domain has also pointed out that laboratory activities may positively affect students' attitudes and interests toward chemistry (Cooper & Kerns, 2006; Okebukola, 1986; Lang, Wong, & Fraser, 2005; Karataş, Coştu, & Cengiz, 2015). Moreover, NRC report also addressed a few goals of laboratory experience including developing scientific reasoning; realizing the complexity and ambiguity of empirical work; having more contemporary view of nature of science; and developing collaboration skills (Singer, Hilton, & Schweingruber, 2006).

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Even though there are many benefits of having laboratory experience, there are also shortcomings of laboratories in chemistry education. As Koretsky and his colleagues (2009) stated that laboratories are resource intensive, both in terms of acquiring and maintaining the equipment and in terms of staffing requirements. Because of these constraints laboratories might not meet initial goals (Koretsky, Kelly, & Gummer, 2011). Especially stuff competencies are very important aspect of laboratory experience (Singer, Hilton, & Schweingruber, 2005). As Cooper and Kerns (2006) noted that chemistry laboratory can be a valuable learning environment only when the instructor understands the purpose of the laboratory experience well and teach it accordingly.

Several studies reported that teachers do not utilize laboratories for many reasons, but mainly for lack of knowledge and laboratory skills (Ayas, Çepni, & Akdeniz, 1993; Nakiboglu and Sarikaya, 1999; Singer, Hilton, & Schweingruber, 2005). There are mainly two different ways of improving laboratory skills for science and especially chemistry teachers: in-service and pre-service training. Training chemistry teachers with an in-service laboratory program may not very feasible because it requires long period of time to improve motor skills than cognitive skills. Thus, it would be hard to find committed teachers to spend at least a few months to improve their laboratory skills. Pre-service training is better way to have future competent chemistry teachers who know how to deal with laboratory experience and experiments. First step of this attempt would be identify and determine current competence level of pre-service chemistry teachers. There is limited number of studies that investigated pre-service chemistry teachers' competencies in laboratory. Research with pre-service science and chemistry teachers demonstrated that their chemistry laboratory skills are very limited and far from being acceptable level (Coştu, Ayas, Çalık, Ünal, & Karataş, 2005). Coştu and his colleagues (2005), however, conducted their study just after the participants completed their general chemistry laboratory course work. So, this does not provide a general picture of graduating pre-service teachers' laboratory competencies. Their findings are not useful to understand how pre-service chemistry teachers' education improves their laboratory skills along the way either. Thus, identifying pre-service chemistry teachers' competencies in laboratory from their first year to graduation would shed light on their laboratory skills development as well as efficiency of the teacher training program. Therefore, this study intends to examine these issues to contribute to chemistry education research literature. These issues are examined in the content of solution chemistry as it is the basic and pre-requisite content of chemistry and chemistry laboratory (de Berg, 2012; Çalık, Ayas, & Coll, 2007; Çalık, Ayas, & Coll, 2009).

This study also addresses the recent call from Towns (2013) regarding future of chemical education research (CER) when she noted "As a starting point, the field needs studies that build an understanding of what learning outcomes – cognitive, psychomotor, and affective – can be achieved and assessed in laboratory across the curriculum" (p. 1108). By focusing on pre-service chemistry teachers' solution preparation competences along their education, this study addresses both cognitive and psychomotor learning outcomes of laboratories and their prolonged effects. In addition, few cross-age studies have been conducted on laboratory competency and this study will seek to address a gap among these studies. Thus, the purpose of this study is to examine pre-service chemistry teachers' laboratory competences in the case of solution preparation across grades. The guiding research questions for this study are:

- What are the pre-service chemistry teachers' competence levels to prepare a solution in certain concentration?
- How do the pre-service chemistry teachers' competence levels change over school year?

Methodology

Design of the Study

As the main purpose of the present study is to investigate the participants' competence levels for certain laboratory skills and then compare them across grades, the methodology employed in this study requires both quantitative and qualitative approaches in descriptive manner. In the process, data were collected via open-ended questions and structured observations and analyzed separately. Then, results merged together to support each other to understand the situation in greater detail which would be called triangulation (Johnson & Christensen, 2008).

Setting and participants

The study was conducted with pre-service chemistry teachers in Turkey. Pre-service chemistry teacher training is an integrated five-year long program in Turkey. During the program, pre-service chemistry teachers take chemistry, pedagogy, and general courses. The pedagogy courses are spread out all over the program, but first year. The first year program includes more general courses such as calculus, physics, oral and written communication, etc. There are no chemistry and/or chemistry laboratory courses in the fifth-year program. The fifth-year program consists of practicum, student counselling, discipline specific educational research, and elective chemistry education courses (e.g. teaching chemistry concepts; ICT in chemistry education; chemistry textbook analysis and evaluation; etc.). Pre-service chemistry teachers are required to take several laboratories from first year to fourth year including general chemistry laboratory I and II (fall and spring semesters of the first year); analytical chemistry laboratory I and II and inorganic chemistry laboratory I and II (fall and spring semesters of the second year); physical chemistry laboratory I and II and organic chemistry laboratory (fall and spring semesters of the third year); and biochemistry laboratory in fall semester of the fourth year (for detailed course work see URL -1).

This study took place at a large university located in North East of Turkey. Approximately 40 pre-service teachers were enrolled in each year of five-year chemistry teacher preparation programme. The participants were recruited just before a class by asking them to provide their e-mail addresses if they are willing to participate in the study after the purpose and the process of the study was briefly explained in absence of the instructor. As seen in Table 1, the participants of the study consist of 88 volunteered pre-service chemistry teachers from different grades. Among these participants six pre-service chemistry teachers from each grade were chosen to further investigate their laboratory competence by employing two solution preparation tasks for them. During the tasks they were observed and briefly interviewed (if there was an ambiguity) about what they are doing. The participants for observation/interview were primarily chosen based on their responses to a test about solution calculation as being low, moderate and high by sending another e-mail to the address that they provided. By this way, it is believed that a general idea would be drawn regarding the class competence level.

Table 1. The participants of the study

Data Collection	Number of participants in each grade					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Solution preparation test	24	21	19	17	14	88
Observation/interview	6	6	6	6	6	30

Data collection

A solution preparation test (SPT) with five open-ended items (see appendix 1) and an solution preparation observation form (SPOF) were utilized in order to collect data about the pre-service chemistry teachers' competence levels regarding solution preparation and laboratory safety precautions.

The SPT consists of five open-ended problem items about preparing solutions from different chemicals (e.g. NH_3, $Kr_2Cr_2O_4$, aqua regia, etc.) and various concentrations types including percentage for liquid and solid solute, molarity, normality, and molality. The questions were adapted from Coştu et al. (2005) and further refined with the help of a panel of researchers including two chemists, two chemistry educators and one linguistic expert. For example, questions become more passive voice if they were active one. A pilot study was carried out with 20 pre-service science teachers who are trained to teach from grade 5 to 8 after experts' edits and suggestions were fulfilled. Based on the pilot study the questions were further revised and refined to clarify meaning and expressions. The pilot study helped revise rubrics that were used in analysis.

The SPOF is a structured observation form with 25 items in three sections including equipment usage competency, solution preparation competency, and laboratory safety competency. Each observable behaviour has three options to be chosen; *Right; Partly Right*, and, *Wrong or Not Observed*. The SPOF was developed for solid-liquid and liquid-liquid solution preparations with a panel of experts consisted of two chemists and two chemistry educators. The participants were asked to complete two tasks: preparing a 3 N 250 ml H_2SO_4 solution from stock solution and preparing a 2 m 100 ml NaOH solution. It needs to be noted that the participants were given pseudo compounds; tap water as H_2SO_4 and granulated salt as NaOH for safety precautions.

Procedure

As Winberg and Berg (2007) discussed the majority of the traditional laboratories have pre-experiment assignments for the students to complete before the experimentation. Usually, these assignments include questions which a calculation similar to the one they will be doing in their final reports is required. Questions might also be asked about the purpose of specific steps of the experimental procedure. In this study, a similar procedure was followed. Before, going into preparation of solutions in certain concentrations (e.g. molar, molal, and normal), all of the participants were given the open-ended test which includes five questions. The participants were asked to solve each problem in the test. After these tests were analyzed, six participants were chosen based on their scores in the test. For each grade, two low, moderate, and high scorers were selected for their solution preparation performance in laboratory. In the laboratory, every participant was observed individually while they were asked to prepare two solutions; one normal (liquid-liquid) and one molal (liquid-solid). Necessary chemicals and chemical equipment (glassware, apparatus, and tools) as well as safety equipment (goggle and apron) were provided. Specifically different types and sizes of glassware were put on the tables in order to see what they choose if they have options. For example, the participants were asked to prepare 250 ml and 3 N H_2SO_4 solution. They were provided three different volumetric flasks in three different volumes including 100 ml, 250 ml, and 500 ml. They were also provided graduated cylinders, Erlenmeyer flasks, and beakers in different sizes as well. The participants were expected to pick the one which is most sensitive and designed for the job that is 250 ml volumetric flask. While the participants were performing, the SPOF was filled and they were asked to talk-out-loud about what they were doing and why they were doing it. By this way, it was aimed to leave no room for hesitation between what is observed and interpreted.

Ethical Considerations

Chemical education research is unique as human subjects might come across physical, mental, and social concerns. This study complies with the RSC's ethical guidance to researchers (Taber, 2014). First of all, all of the participants were volunteers for the study. They were explained about the purpose and process of the study, their responsibilities, as well as possible benefits and risks. Agreement between the participants and the researcher guaranteed the privacy of the participants. Laboratory activities require safety precautions while conducting experiments. In this study, two solution preparation tasks were undergone by the participants. Solution preparations, in this study, involved using chemicals and glassware no other chemical processes (heating, evaporating, distillation, etc.). The participants were asked to prepare acid and base solutions, but tap water and granulated rock salt were provided as pseudo compounds.

In other words, chemicals that were used for the study are not hazardous. Thus, there was no potential health risk for the participants more than preparing a glass of lemonade.

Data analysis

In order to have credible analysis, a rubric as seen in Table 2 was developed for the problems on the test. Similarly another rubric was developed for solution preparation while developing the SPOF by taking into account problems; an appropriate laboratory equipment usage; laboratory safety; and solution preparation as seen in Table 2.

Table 2. The rubric for analysis of the SPT and SPOF problems

Theme	Category	Grading Criteria for SPT	P
Solution problem	Correct	Demonstrating right solution and correct result	2
	Partly Correct	Demonstrating right solution, but incorrect unit of conversion and calculations Or one or more missteps for the solution	1
	Wrong or N/R	Wrong solutions; Non filled items; or "I do not know," "I have no idea" types of responses	0
	Category	**Grading Criteria for SPOF**	
Laboratory Equipment Usage	Right	Using right equipment appropriately	2
	Partly Right	Not using some of the required equipment or misusing the right equipment	1
	Wrong or N/O	Not using the required equipment or use them in a wrong way	0
Solution Preparation	Right	Solving the problem correctly and using right laboratory equipment correctly or partly correctly (or one wrong)	2
	Partly right	Solving the problem correctly, but cannot use right equipment properly Not solved the problem correctly, but used the right equipment properly	1
	Wrong	Cannot solve the problem and cannot use right equipment properly	0
Laboratory Safety	Right	Taking into account all of the safety measures identified in the SPOF	2
	Partly right	Taking into account three or more safety measures identified in the SPOF	1
	Wrong	Taking into account two or less safety measures identified in the SPOF	0

The rubric was developed based on the descriptions defined by Coştu et al. (2005) and guidelines provided by Mertler (2001). The rubric was used while observing the participants while they were performing the task that was given about solution preparation. Similar to the SPT and the SPOF development process, a panel of experts consisted of two chemists and two chemistry educators was advised in the rubric development process.

Results

Results from SPT

The collected data were analyzed based on the rubric in Table 2. The results from these analyses were presented accordingly. Descriptive results from the paper-pencil test about solution problems are presented and then comparison between the grades is provided.

As seen in Table 3, the first question which asked to prepare a dilute molar solution from a higher concentration of NH_3(aq) solution was responded with the most correct answers. On the other hand, the fifth question which asked to prepare 0.02 molal $K_2Cr_2O_4$(aq) solution was responded with the most wrong answers. The first question was answered most correctly by all grade levels, but fifth-years. Only 50% of the fifth-years answered the first question correctly and interestingly almost all of the fifth-years gave right answer for the third question which asked to prepare *aqua regia*. Preparing 3N solution from a polyprotic acid (H_3PO_4) was responded least correctly: only 27% of the participants' responses were right and 28% of them gave partly correct answers.

Table 3. The pre-service chemistry teachers' answers to solution problems

Grades	N	The pre-service chemistry teachers' responses														
		Q1 (%)			Q2 (%)			Q3 (%)			Q4 (%)			Q5 (%)		
		C	P	N	C	P	N	C	P	N	C	P	N	C	P	N
First-Year	24	96	4	-	67	8	21	29	-	71	25	46	29	46	-	54
Second-Year	14	71	22	7	43	14	43	64	-	36	7	7	86	36	7	57
Third-Year	19	90	5	5	26	26	48	48	5	47	26	53	21	42	26	32
Forth-Year	17	88	-	12	47	6	47	88	-	12	41	12	47	76	-	24
Fifth-Year	14	50	14	36	29	-	71	93	-	7	36	21	43	21	-	79
Average	18	79	9	12	42	11	47	64	1	35	27	28	45	44	7	49

C: Correct; P: Partly correct; N: Wrong or no response

The average score for the whole sample was calculated as 5.83 out of 10 and standard deviation is 2.33 which mean that there is a wide-range of responses. When compare the pre-service teachers' grades, the fourth-year pre-service teachers' mean score is the highest and the second-year pre-service teachers' is the lowest as seen in Table 4. When ANOVA was run for the test scores presented in Table 4 to compare effects of years of official training to answers solution problems. Significant differences were found at the $p<0.05$ level between the participants' school years and their test scores, both total and itemized, with one exception [F_{Total} (4, 83) = 3.38, p = 0.013; F_{Q1} = 4.52; F_{Q3} = 8.50, p= 0.000; F_{Q4} = 2.92, p = 0.026; F_{Q5} = 5.28, p = 0.001]. There was no significant difference between school years and second item of the test which is about preparing a solution based on mass percentage [F_{Q2}(4, 83) = 2.23, p = 0.072].

Table 4. The pre-service chemistry teachers' means for solution problem scores

Grades	The Participants' Mean Scores from the Test Items											
	Q1		Q2		Q3		Q4		Q5		Total	
	M	Sd	M	Sd	M	Sd	M	Sd	M	Sd	M	Sd
First-Year	1.93	0.20	1.42	0.88	0.58	0.93	1.00	0.78	0.92	1.02	5.88	2.05
Second-Year	1.64	0.63	1.00	0.96	1.29	0.99	0.21	0.58	0.64	0.93	4.79	2.08
Third-Year	1.84	0.50	0.79	0.86	1.00	1.00	1.11	0.74	1.11	0.88	5.84	2.34
Forth-Year	1.76	0.66	1.00	1.00	1.88	0.49	0.94	0.97	1.76	0.67	7.35	2.23
Fifth-Year	1.14	0.95	0.57	0.94	1.86	0.54	0.93	0.92	0.43	0.85	4.93	2.40
Average	1.73	0.64	1.00	0.95	1.24	0.97	0.88	0.84	1.00	0.97	5.83	2.33

As seen in Table 5, post hoc comparisons using the Tukey HSD test indicated that the mean score of the whole test for second-years (M = 4.79, Sd = 2.08) was significantly different than the fourth-years (M = 7.35, Sd = 2.23) in favour of fourth-years. Similarly, mean score of the whole test for fourth-years was significantly different than the fifth-years (M = 4.93, Sd = 2.40) in favour of fourth-years. Post hoc comparisons were also utilized for each item of the test.

Table 5. Significant Tukey test results at p<0.05 level

Grades	Second-Year	Third-Year	Fourth-Year	Fifth-Year
First-Year	Q4 (1st year)		Q3 (4th year) Q5 (4th year)	Q1 (1st year); Q3 (5th year)
Second-Year		Q4 (3rd year)	Total (4th year) Q5 (4th year)	
Third-Year			Q3 (4th year)	Q1 (3rd year), Q3 (5th year)
Fourth-Year				Total (4th year) Q1 (4th year) Q5 (4th year)

No significant difference was found between grades for question two (Q2) which asks to prepare a solution in percent composition by mass. The Tukey HSD test indicated that the mean score of Question 1 (Q1) for the fifth-years ($M = 1.14$, $Sd = 0.95$) was significantly different than the first ($M = 1.93$, $Sd = 0.20$), third ($M = 1.84$, $Sd = 0.50$), and fourth-years ($M = 1.76$, $Sd = 0.66$). For Question 3 (Q3), mean scores for first ($M = 0.58$, $Sd = 0.93$) and third years ($M = 1.00$, $Sd = 1.00$) significantly different than fourth ($M = 1.88$, $Sd = 0.49$) and fifth-years ($M = 1.86$, $Sd = 0.54$). For Question 4 (Q4), mean scores for second-years ($M = 0.21$, $Sd = 0.58$) was significantly different from first ($M = 1.00$, $Sd = 0.78$) and third-years ($M = 1.11$, $Sd = 0.74$). When the students' scores compared for Question 5 (Q5), mean scores for fourth-years ($M = 1.76$, $Sd = 0.67$) was significantly different from first ($M = 0.92$, $Sd = 1.02$), second ($M = 0.64$, $Sd = 0.93$), and fifth-years ($M = 0.43$, $Sd = 0.85$).

Results from solution preparation in laboratory

The participants' solution preparation was analysed in three main categories based on SPOF and the think-aloud interview protocol; solution preparation, laboratory safety, and equipment usage for liquid-liquid and liquid-solid solutions. As seen in Table 6, a few of the participants lacked necessary skills and more than half of the participants could not show or perform necessary behaviours correctly. The participants generally had deficiencies in laboratory safety precautions. Only four out of thirty participants took into account all laboratory safety codes listed in the SPOF. The majority of the participants partially obeyed the safety codes for both solid-liquid and liquid-liquid solutions. Many participants did not wear goggles while preparing solutions.

Table 6. Categorized results from the SPOF

Themes	Grades	**Behaviours**							
		Liquid-liquid				Solid-liquid			
		R	PR	W	X	R	PR	W	X
Laboratory Equipment Usage	1st Year	2	3	1	1.17	4	2	-	1.67
	2nd Year	3	3	-	1.50	6	-	-	2.00
	3rd Year	5	1	-	1.83	1	3	1	0.83
	4th Year	3	3	-	1.50	5	1	-	1.83
	5th Year	2	4	-	1.33	3	2	1	1.33
	Total	15	14	1	1.47	19	8	2	1.50
Solution Preparation	1st Year	3	3	-	1.50	3	3	-	1.50
	2nd Year	3	-	3	1.00	3	3	-	1.50
	3rd Year	3	3	-	1.50	4	2	-	1.67
	4th Year	3	3	-	1.50	4	2	-	1.67
	5th Year	1	5	-	1.17	1	1	4	0.50
	Total	13	14	3	1.33	15	11	4	1.37
Laboratory Safety	1st Year	1	4	1	1.00	1	4	1	1.00
	2nd Year	1	4	1	1.00	1	4	1	1.00
	3rd Year	-	6	-	1.00	-	6	-	1.00
	4th Year	2	4	-	1.33	2	4	-	1.33
	5th Year	-	5	1	0.83	-	6	-	1.00
	Total	4	23	3	1.00	4	24	2	1.07

R: Right, PR: Partly right, W: Wrong or no response, X: Calculated mean score based on rubric in Table 2

For each category, the participants' average scores by grade were calculated and illustrated in Table 6. As a three-point scale rubric (see Table 2) was utilized, average scores were categorized as 0 to 0.66 is poor, 0.67 to 1.33 is moderate, and 1.34 and over is good. When three main categories are considered, obeying the laboratory safety regulations is the lowest of all, but is at moderate level. Except liquid-liquid solution preparation, the participants' overall equipment usage and solution preparation skills are considered as good. When school year is examined, on the other hand, only 5th year pre-service chemistry teachers' solid-liquid solution preparation is considered poor. Rest of them is moderate or good.

In order to illustrate change in pre-service chemistry teachers' chemistry laboratory competencies, a line chart was drawn for each theme. As seen in Figure 1, while the participants preparing a liquid-liquid solution, they showed lower equipment usage skills than preparing a liquid-solid solution at all years, except the third year. The third year participants' equipment usage skills are against the general trend as they performed well for liquid-liquid solutions, but not that well for liquid-solid solution. Most of the wrong usage comes from not measuring the volume precisely, not choosing an appropriate size of volumetric flask or not using one at all. Another common mistake takes place when the participants try to weight the solid. A few of them did not use spatula to take solid from its container, they poured it directly to a beaker/paper then refilled extra substance into the container.

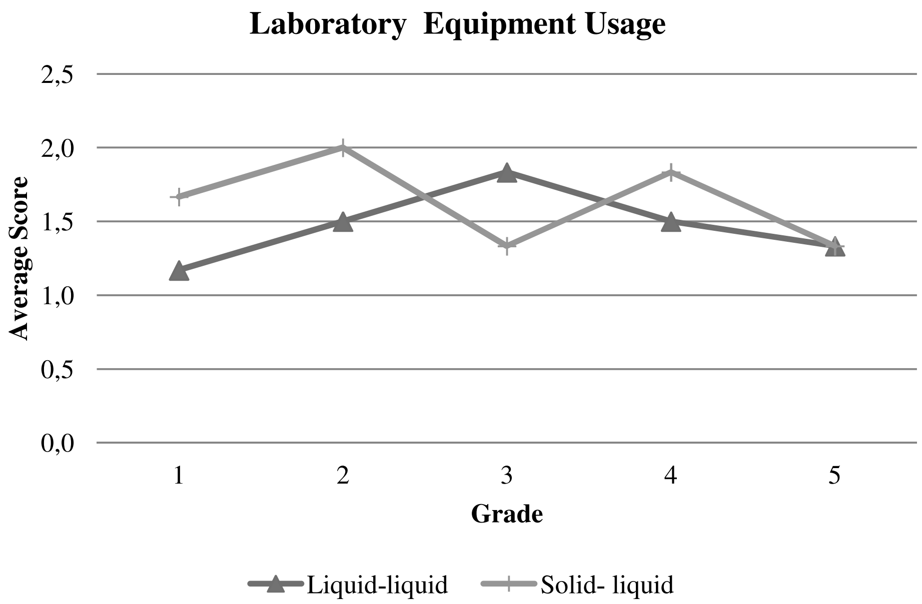

Figure 1. Laboratory equipment usage by school year

Figure 2 illustrates solution preparation skills of the pre-service chemistry teachers. There is a slight increase by years of education except the fifth-year. As seen in the Figure 2, fifth year pre-service chemistry teachers' both liquid-liquid and liquid-solid solution preparation skills show a decrease when compared rest of the participants.

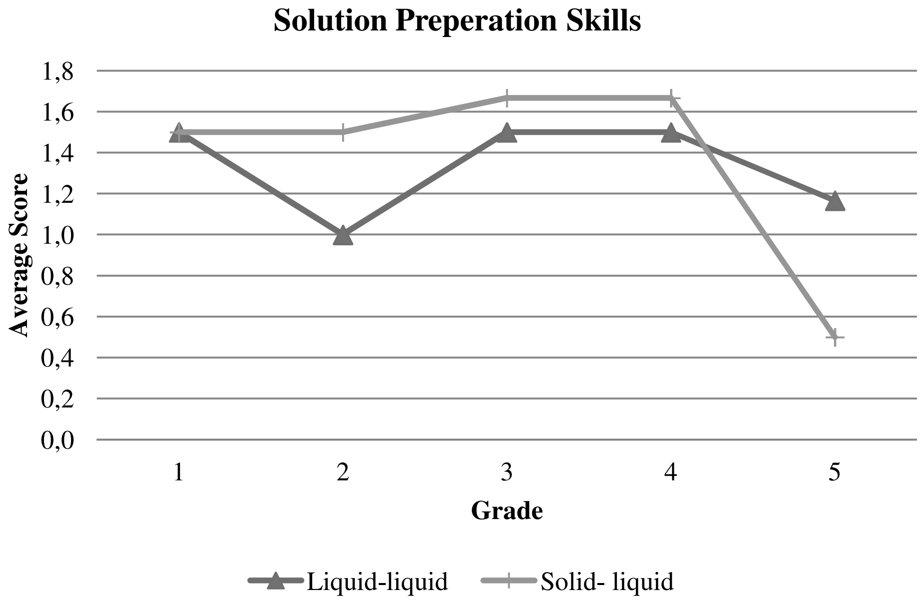

Figure 2. Solution preparation skills by school year

Another category that was examined via SPOF is laboratory safety which the participants illustrated the lowest average scores. As seen in Figure 3, there is no difference between solution types for the participants except the fifth-years. Even though there is an increase in fourth-year regarding their following laboratory safety regulations, a rapid decrease is observed from fourth-year to fifth-year. More than half of the participants (N=17) did not wear goggles while conducting their duties. This is the most common violation against laboratory safety regulations. Another safety precaution that was not taken into account by 30% of the participants (N=9) is not using appropriate place to conduct experiments including not using fume hood. Even though half of the participants had long hair, one third of them did not use hair clip to fix them was the third most common violation.

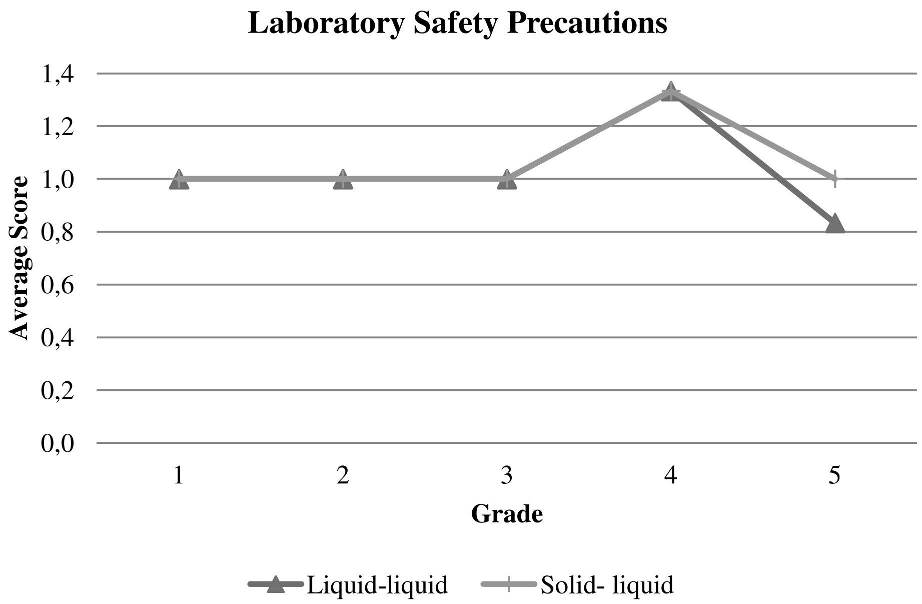

Figure 3. Laboratory safety precautions by school year

Discussions and Conclusions

The purpose of this study is to determine and compare pre-service chemistry teachers' laboratory competences in the case of solution preparation. The participants' laboratory competencies were examined in two sequent stages; theoretical and practical. The participants' overall problem solving skills to prepare a solution in certain concentration is moderate (average score is 5.83 out of 10; see Table 4 and Table 6). But, their average scores for calculating the right amount of solute varied based on the solution and concentration types. The highest average score was 1.73 out of 2 to prepare a dilute molar solution from a higher concentration of NH_3(aq). The participants generally used a common equation for molarity which is located in textbooks for their calculations. When a similar question is asked to prepare 3 N phosphoric acid solution, most of them stuck with below average scores. First, they calculated molarity of stock solution of phosphoric acid. Then, they tried to convert it to normality. Most of the participants who solved the first problem were successful at the first stage, but they failed while converting molarity to normality as they either did not take into account equivalency or miscalculated it (Coştu et al., 2005). This would be as a consequence of not using normality solutions as often as molarity solutions in their laboratory classes. The participants' responses for normality question are interesting in another way. As seen in Table 3, only 12% of the participants' responses to the first questions are either wrong or unrelated, but 45% of the responses for the fourth question fit in this category. This may be the result of not being aware of the relationship between molarity and normality concentrations or believing that the normality is harder topic. It is believed that the second option is more probable because adding correct and partly correct responses of the normality question makes 55% of the total responses. If the participants calculated molarity of the stock acid solution before converting it to normality, they would have taken partly credit. It means that they did not even try it or tried it in a different way as they think it is hard to solve. As Karataş, Bodner, and Ünal (2015) indicated, beliefs might be one of the main factors that affect learning. Similarly, self-efficacy is claimed to play a major role in academic achievement as it may also cause the participants not to be able to solve the normality problem (Bandura, Barbaranelli, Caprara & Pastorelli, 1996).

In addition to normality, correct responses to molality and percent composition (by mass) are below 50% which is believed is quite low. This indicates that the pre-service chemistry teachers did not comprehend the solution chemistry well. When it is looked from a developmental perspective, there is no clear indication of comprehension through school years. Regardless, a significant difference was found between second years and fourth years as well as fourth years and fifth years (see Table 4 and 5). The fifth-year pre-service teachers' average score from the test is 4.93 out of 10 which is the second worst after the second-years. The same trend is also apparent in solution preparation in laboratory that is the fifth-year participants' problem solving skills are worse than rest of the participants (see Figure 2). The fifth year program does not have any chemistry or chemistry laboratory courses (see URL 1). Therefore, lower scores of solving concentration problems would be stemmed from absence of chemistry courses. Fourth-year is very active in terms of chemistry as well as chemistry education courses. The pre-service chemistry teachers took methods, instructional technology and material design courses which require developing and employing teaching materials and models based on chemistry topics. Even though it is claimed that active participation may enhance learning permanency, our findings somehow contradicts this prediction as fifth years problem solving skills significantly lower than their successors (fourth years). Research in retention implies that in the absence of retrieval practice, recalling information simply decays over time as a result of memory trace loss (Roediger & Butler, 2011; Wixted, 2004). Atkinson–Shiffrin's dual store model of memory suggests that the longer an item stays in short-term memory, the stronger its association becomes in long-term memory (Atkinson & Shiffrin, 1968). These two claims imply that maintenance rehearsal including several recalls and retrievals/reminders of memory would be necessary to preserve long term memories (Wixted, 2004). In addition, well-organized encoding process in short-term memory might help retention from long-term memory, illorganized (dissociated or confused confrontation) encoding might cause opposite effect (Ruchkin, Grafman, Cameron, & Berndt, 2003). Open-ended tasks and active participation – involves episodic and autobiographic memory – also help encoding and retention (Arthur Jr, Bennett Jr, Stanush, & McNelly, 1998). Thus, nature of chemistry laboratory class would have a great effect on retention or forgetting. Chemistry laboratory classes for the pre-service teachers are generally performed in large groups. Each class member unlikely gets a chance to prepare chemical solutions. The nature of experiments and laboratory manuals which look like cook-book recipe where students simply follow the instructions without understanding concepts and process would be the reason of fast memory decay of the participants (Gallet, 1998).

The pre-service teachers made mistakes especially while calculating and converting the units. Even though these mistakes seem technical not chemical, they still affects how teachers prepare solutions as a solution with wrong/unknown concentration may cause unexpected results in a laboratory class even though solutions are not prepared for research. This might affect sensitiveness of the experiments including rate of reaction, equilibrium constant, and so on. Another mistake that affect obtaining sensitive results takes place when the participants were measuring the liquid level as few read the top of the concave meniscus instead of the bottom. This is very basic knowledge about observation, but few participants seemed not to be aware of that or to care about it (Coştu et al., 2005). The members of the laboratory class are generally expected to read and understand related parts of the laboratory manual before conducting experiments. What happens is a little different than expected. Thus, ICT based pre-laboratory exercises that aim aforementioned aspects would be an effective way to avoid those simple mistakes (Chittleborough, Mocerino & Treagust, 2007).

Laboratory equipment usage was examined while the participants were solving the given tasks of preparing liquid-liquid and solid-liquid solutions. Generally equipment usage is correct or partly correct. One of the major mistakes is not using right equipment for the task including volumetric flask and spatula. A few participants used graduated cylinder for solution preparation. Since there are only a few of them, it is believed that the participants are not aware of using volumetric flask rather than it is common way of solution preparation that happens in their laboratory classes. On the other hand, the reason of using the graduated cylinder may stem from their practical usage habits as a graduated cylinder can be used to measure liquids when no precise measurement is needed. A few of the participants did not use a spatula while taking solid chemicals from the container. This is also very basic knowledge and it can be even considered as common sense which may not require training. Similar to the case of using graduated cylinder instead of volumetric flask, pouring directly from the container seems to be more practical for the participants. Thus, it is inferred that laboratory work may enforce the participants to make decisions to develop new skills that are more practical for them, but may not be suitable for chemistry laboratory. These laboratory behaviours would be explained by expected utility theory (Briggs, 2014). The expected utility of an act is a weighted average of the *utilities* of each of its possible outcomes, where the utility of an outcome measures the extent to which that outcome is preferred. Thus, the higher the expected utility, the better the act to be chosen. In our case, more practical usage of equipment might be perceived more utilitarian (Lengwiller, 2009).

Aside these, a similar trend was observed when laboratory safety is considered. Many participants neither wear goggles nor fix their hair, nor take into account acid spatters. These might also be explained by expected utility theory and shows their risk analysis as more than half of the participants did not wear goggles means they do not see it as a necessary act to protect their eyes as probability of having such an accident is very low, but wearing a goggle is *irritating* (a general student complain).

Every study has some limitations including the current one. In this study, pre-service chemistry teachers' laboratory skills were examined across years. There are several variables that directly or indirectly affected the results that are either cannot be identified or controlled. Some of the limitations come from research method that was chosen to investigate the participants' laboratory skills in a developmental manner. As different student cohorts were chosen for different school years they had different backgrounds. They had, for example, different instructors for each class. As a social group, they might have micro culture including hard-working class or lazy class. So, these and similar circumstances might play a role over the results. However, two phase approach would address some of these limitations as in the second phase good, moderate and bad achievers were chosen to illustrate a general view. Regardless, there were many variables which were not able to be controlled. Thus, a longitudinal approach would be adopted to overcome some of the limitations in the future.

Implications for Teaching and Teacher Training

Although chemistry laboratory is believed to be a part of chemistry learning and is a routine part of the chemistry curriculum, student learning in the laboratory has not been examined very well (Towns, 2013). As a starting point, this study respond to the call in order to contribute building an understanding of what learning outcomes including cognitive, psychomotor, and affective can be achieved and assessed in laboratory across the curriculum. It seems that the more chemistry laboratory courses are taken, the better solution chemistry understanding is achieved. However, prolonged effects of the chemistry teacher training program send mix signals. It looks that fifth-year program does not support the participants' cognitive and psychomotor chemistry development as it focuses on more practicum and other educational courses. As a decrease is seen not only problem solving stage, but also safety and laboratory equipment usage stages, traditional teaching should be reconsidered. Thus, more chemistry applications would be integrated into teachers training programs even while they focus on more pedagogical aspects. As the students are better for certain solution problems in certain grades, this indicates that their education at that grade level would be related to those solution types. Thus, it is suggested that more computer and/or mobile technology assistance and other opportunities should be considered to help students retain what they have learned from their classes and laboratories. As Lunetta, Hofstein and Clough (2007) suggested well planned laboratory and simulation experiences would put students into inquiry environment where students would be active not only "hands-on" but also "minds-on." Research in learning and retention also suggests well-encoding and rehearsals would slow down retention loss (Cowan, 2008). Moreover, laboratory activities should be part of PCK packages of methods courses. Instead of just focusing on laboratory types and approaches in teaching, they should be employed to be a good illustration as well.

The participants gained the lowest scores from safety aspect of the study. Safety elements include proper clothing, cleaning and waste disposal as well as special handling. For example, many participants did not wear goggles properly or not wear them at al while they were preparing the acid-base solutions. There was no restriction or authoritarian guidance for safety precautions for research purposes. It seems they were not aware the risk. So, it is a humble prediction that they would not pay attention to safety issues greatly while teaching. Thus, while teaching laboratory safety, focus should have been to affective learning outcomes in accord with rational or cognitive ones (Taber, 2015).

It looks that the pre-service chemistry teachers have conceptual issues about solution preparation, but some of the issues are not conceptual, but rather psychological as it is seen in normality problem case. They solved molarity problem properly and they know about normality by definition, but they could not solve the normality problem. Many of them could not get partial credit from the problem as they did not attempt to solve it. It seems that they did not believe themselves that they can solve the problem. So, their self-efficacy level is considered low for certain solution problems. Positive and successful attempts would raise self-efficacy in a certain field. Therefore, more recitation hours should be allocated for these students to further exercise over the concepts and problems as experience of mastery. Most of the cases, standard solutions were provided by laboratory assistants and/or technicians. As students or pre-service teachers may not have a chance to calculate and prepare a solution, their experience would be limited to "vicarious" level. As Reid and Shah (2007) asserted, nature of chemistry laboratory should be reconsidered. Students should be allowed – under guidance and control of the teaching assistants

– to prepare their own solutions for the experiment. This increases their chemistry laboratory as well as chemistry conceptions competence level. It would affect students' self-efficacy in a positive way as well.

This study employed a cross-grade approach to examine solution preparation skills of pre-service chemistry teachers. Developmental studies are crucial to evaluate and improve a programme. But, as discussed this approach brings about many limitations as well. Thus, a longitudinal study approach should be taken into account to address these limitations to better understand how laboratory could affect learning and retention. Aside this, shorter (a semester long) but deeper investigation about group/team work and virtual laboratory should be considered while designing a new study to explore laboratory effect. Another suggestion for researchers who are interested in laboratory work would be about focusing on problem solving stage of solutions. Think-aloud protocol was a useful tool for this study to confirm observed behaviours. But, this study did not intend to examine problem solving strategies and models of the participants. Further research might be fruitful to illuminate this area as it is the key area for chemists and chemistry teaching.

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Appendix 1: Solution Preparation Test (SPT)

Q1. How much NH_3 stock solution with d= 0.9 g/cm^3 density and 10% by mass is needed to prepare 0.2 M 100 ml NH_3 solution? (N: 14 g/mol and H: 1g/mol)
Q2. In order to prepare 150 ml of a 10% by mass $KHSO_4$ solution, how many grams of $KHSO_4$ are needed? (For solution d=1.04 g/cm^3, K: 39 g/mol, S: 32 g/mol, O: 16 g/mol, H: 1 g/mol)
Q3. *Agua-regia* would be prepared in 3:1 ratio of HNO_3:HCl. According to this information how could you prepare 90 ml *aqua-regia*? (O: 16 g/mol, N: 14 g/mol, Cl: 35.5 g/mol)
Q4. How much H_3PO_4 stock solution with d= 1.70g/cm^3 and 85% by mass is needed to prepare 3 N 200 ml H_3PO_4? (P: 31 g/mol, O: 16 g/mol, H: 1 g/mol)
Q5. How many grams of $K_2Cr_2O_4$ are needed to prepare 0.02 m (molal) solution in 100 g of water? (K: 39 g/mol, Cr: 52 g/mol, O: 16 g/mol)

Appendix 2: Solution Preparation Observation Form (SPOF)

	Liquid-Liquid			Solid-Liquid		
	R	PR	W	R	PR	W
Laboratory Equipment Usage						
Solution container (volumetric flask (250 ml for the first one and 100 ml for the second one)						
Propipetter						
Pipette						
Pure water washing bottle						
Spatula						
Solution Preparation Skills						
Did s/he solve the problem?						
Did s/he check the cleanness of the equipments?						
Did s/he pour/get certain amount from the stock solution/substance then using from there in order to protect purity?						
Can s/he use pipette and propipetter properly while taking liquid?						
Did s/he use pure water or tap water as solvent?						
Can s/he measure the right amount for liquid (concave, convex)?						
Did s/he take into account order of mixing chemicals with the water? (For H_2SO_4)						
Did s/he fill up the solution (container/volumetric flask) with the solvent? (For H_2SO_4)						
Did s/he use digital scale properly?						
Did s/he check tare of the glass before measuring the amount of chemical (for solids)						
Did s/he add up 100 ml of solvent to prepare solution?						
Did s/he use the right equipment to take solid chemicals from the stock?						
Did s/he solve the solid before adding water to complete solution?						
Laboratory Safety Precautions						
Did s/he wear apron?						
Did s/he wear goggles?						
Did s/he use hood?						
Was s/he aware that s/he needs to protect her/his eyes when open a lid?						
Did the ones who have long hair clip their hair?						
Did s/he behave carefully for splitting?						
Was s/he aware that no food and beverages are allowed in laboratory?						