Comparing science process skills of prospective science teachers: A cross-sectional study

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Abstract

This study was conducted with the purpose of examining how Prospective Science Teachers' (PST) Science Process Skills (SPS) develop according to different grades. In this study, a cross-sectional research approach in the form of a case study was used. The sample group consisted of a total number of 102 undergraduate students who were selected from four different grades [(First Grade = Freshman) N=33; (Second Grade = Sophomores) N= 23; (Third Grade = Juniors) N= 27; (Fourth Grade = Seniors) N= 34] at the Department of Science Teacher Education, in the Faculty of Education, the University of Giresun. As the data collection tool, a test of assessing science process skills included 12 questions (9 multiple choice and 3 open ended questions) was used in this study. The mean SPS scores for students from different grades were compared. Kruskall-Wallis H test was used to determine whether or not there were significant differences in the levels of the different grades PST' SPS. Although PST were expected to develop their SPS over the increasing grade levels from the first to the fourth grade, the findings of this study show that there is no linear development.

Keywords: Science process skills, prospective science teachers, cross-sectional approach.

Introduction

Recent studies on curriculum development and assessment give specific emphasis on students' scientific approach to events, their knowledge acquisition and their ability to find solutions to problems (MNE, 2006). Although scientific research in the area of science is widely adopted by many countries, internationally conducted TIMSS studies reveal that their findings are not implemented in most countries (Bağcı Kılıç, 2003). The aim of science education is for science to be taught through scientific inquiry that develops students' science process skills (SPS). Although the need to teach the ways of reaching knowledge is known by many countries, the results of internationally conducted TIMSS study show that this isn't realized in many countries (Bağcı Kılıç, 2003). According to 1999-2007 results of TIMSS study, Turkey is remained significantly below the average level (URL-1-2, 2009). Taking into consideration that TIMSS also measures SPS, Turkey's

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remaining below the average level may be interpreted that students have very low level of SPS.

PISA is another international assessment study in which many countries regularly participate. The reason why Turkey takes part in PISA is to determine both our position at international level with respect to some references and the shortcomings of our education system toward identifying what precautions to take in order to increase the quality of education. PISA 2003 results have been used as a source in curriculum development studies and various research studies in the area of education (URL-3, 2009). In Turkey, Science and Technology curriculum was restructured in 2004 taking these factors into consideration. General aims of the restructured Science and Technology curriculum were explained and the targets of the program were introduced. When the targets of Science and Technology program are examined, it is possible to see that 'educating all students to be scientifically literate regardless of their individual differences' is among the most important aims of education. Scientific literacy is defined as developing individuals' abilities of investigating, questioning, critical thinking, problem solving, decision making, being life-long learning individuals, and a set of ability, attitude and understanding regarding science to sustain individuals' curiosity about their environment and the world (MNE, 2006). Science literacy is a key goal of science education (American Association for the Advancement of Science [AAAS, 1993]; National Research Council [NRC, 1996]). The Educating scientifically literate individuals, however, is possible not through passing knowledge onto individuals but through teaching them and enabling them to adopt to use the ways to gain scientific knowledge. In this respect, SPS is highly important in teaching ways of reaching knowledge. SPS are mainly classified as basic skills and integrated process skills, the former involving observing, measuring, classifying, using number relationships, predicting, drawing conclusion, communicating and the latter involving identifying and controlling variables, formulating and testing hypotheses, operational describing, experimenting, and commenting variables (Kanlı & Yağbasan, 2008). While SPS are widely used in science, they are also used in real life contexts. They are required for explaining how real life events have occurred. SPS involves creative and critical thinking alongside scientific thinking. It is known that having those who can think creatively and critically are an important factor in the development of a country. Therefore, it is possible to say that SPS can be viewed as a measure of creativity for making scientific discoveries and contributing to countries' development. Aktamış and Ergin (2007), in their

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study that aimed to determine the relationship between SPS and scientific creativity, Aktamış and Ergin (2007) gave students various activities and administered after the intervention SPS measurement test and scientific creativity scale to twenty 7th grade students. Additionally, they analyzed students' worksheets in terms of SPS and scientific creativity. As the result of their study, they found a meaningful relationship between SPS and scientific creativity. SPS and scientific creativity mutually support each other (Roberts 2003). Therefore, it is possible to say that SPS is also a measure of creativity, which plays a significant role in contributing to scientific discoveries toward the good of society. Therefore, the need of providing students with SPS comes to the fore toward the development of creative individuals. Teachers have some important responsibilities such as organizing the teaching environment and teaching activities, teaching the ways of reaching knowledge, developing students' SPS and following students' SPS level of development and enabling students to develop their SPS (Ash, 1993; Harlen, 1999; Bağcı Kılıç, 2003; Arslan & Tertemiz, 2004).

Many researchers have investigated studies related to SPS in science education (Lazarowitz & Huppert, 1993; Brotherton & Preece, 1995; Harlen, 1999; Beaumont-Walters & Soyibo, 2001; Huppert, Michal & Lazarowitz, 2002; Tan & Temiz, 2003; Harrell & Bailer, 2004; Saat, 2004; Harrell & Bailer, 2004; Wilke & Straits, 2005; Monhardt & Monhardt, 2006; Karahan, 2006; Bilgin, 2006; Kanlı, 2007; Koray, Köksal, Özdemir, & Presley, 2007; Temiz, 2007; Farsakoğlu et al., 2008; Karslı & Şahin, 2009; Hotaman 2008; Kılıç, Haymana & Bozyılmaz, 2008; Metin & Bilişçi 2009; Karslı, 2011). The foremost among these studies are those that examine the effect of using different teaching methods on students' SPS and academic success (Campbell, 1979; Lee et al., 2002; Saat, 2004; Karahan, 2006; Tatar, 2006; Azar et al., 2006; Kanlı, 2007; Koray et al., 2007; Dori & Sasson, 2008). Most of these research studies showed that there were positive relationships between the students' SPS and their achievements in science and also between the students' positive attitudes toward science and their achievements in science (Colley, 2006; Bilgin, 2006; Wilke & Straits, 2006; Kesamang & Taiwo, 2002; Beaumont Walters & Soyibo, 2001; Bybee, 2000; Schibeci & Riley, 1986). Therefore, science teachers should be aware of the importance of improving the students' SPS and positive attitudes toward science, because they are strong predictors of the students' achievement in science.

Farsakoğlu et al (2008) found out that seniors PST did not know SPS and confused it with concepts like Bloom's taxonomy's (cognitive domain) and Piaget's

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development stages. Karslı and Şahin (2009) prepared a worksheet based on SPS in order to develop PST' SPS in laboratories and to promote their awareness of SPS. What attracts attention is the small number of studies carried out on the SPS of teachers and prospective teachers (Farsakoğlu et al., 2008; Karslı, Şahin & Ayas, 2009; Sinan & Uşak, 2011). However, there was no cross-sectional research study on prospective teachers to show how SPS develops over time. Cross-sectional research is generally carried out with the purpose of identifying misconceptions and comparing developmental differences at different ages (Çalık & Ayas, 2005; Saka et al., 2006; Şahin et al., 2008). Studies that use cross-sectional research method are effective in improving activities with respect to teaching concepts and in informing teachers how a concept develops in an individual. Carrying out a cross-sectional study on SPS is believed to be important in identifying whether or not there is a relationship between SPS and different grades. Comparing SPS at different grades is believed to enlighten researchers in their studies toward observing the development of SPS in prospective teachers, toward elimination of shortcomings that have been identified and toward increasing the quality in education.

The purpose of this study is to examine how prospective science teachers' SPS develop according to different grades.

Method

The Sample

The study was carried out with a cross-sectional research. Cross-sectional research method is used with the purpose of investigating over a short period of time samples at developmentally different grades and comparing sample groups (Çepni, 2007). The study was carried out in the academic year of 2008-2009 at the Faculty of Education, University of Giresun in Turkey. The sample group consists of a total number of 102 undergraduate students [(First Grade= Freshman) N=33; (Second Grade= Sophomores) N= 23; (Third Grade= Juniors) N= 27; (Fourth Grade= Seniors) N= 34] who were selected from four different grades at the Department of Elementary Science Teacher Training.

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Collecting Data

As the data collection tool, 12 questions were selected from a pool of questions on SPS, which was prepared by Temiz (2007) for assessing science process skills. The SPS test as the data collection tool was applied to all groups. The test that included 3 open ended questions was applied to determine the awareness levels of PST and their views on the improvement of their own SPS. The 12 questions in the SPS test were selected from each module of 'Test for Assessing Science Process Skills' (Temiz, 2007). 9 multiple choice and 3 open ended questions were selected from a pool of questions consisting 6 modules. From the modules, questions related to mechanics (movement, speed, acceleration, movement on slopes, periodic movement) were selected, considering that PST developmentally at different grades were familiar with them. The names of these modules were respectively "identifying variables and formulating hypotheses", "controlling variables and experimenting", "collecting data, preparing data table", "drawing graph", "interpreting the data and reading graph", "identifying variables and formulating hypotheses". In the test, there were four multiple choice questions in the first module, one multiple choice question in the second module, one open-ended question in the third module, one open-ended question in the fourth module, four multiple choice questions in the fifth module, and one open-ended question involving three phases in the sixth module.

A sample item from the module of identifying variables and formulating hypotheses developed by Temiz (2007) is now presented in more detail below:

Question 4. Aslı made an inclined plane in the figure using a carton (cardboard) and book. When she put a ball on the indicated plane, observed it to go by rolling down. Aslı decided to investigate depending on what are the distance a ball dropped from the indicated plane can go until it stops.

1. In your opinion, what are the variables affecting the distance a ball can go until it stops?

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2. Please write a hypothesis can be tested using one of the variables determined above.

3. Please write a hypothesis can be tested using one of the variables determined above.

a) Depended variable:

b) Independent variable:

c) Controlled variables:

Data Analysis

Students answering correctly each question from each module received four points from Module 1, one point from Module 2, sixteen points from Module 3, twenty-two points from Module 4, four points from Module 5 and ten points from Module 6. Correct and incorrect answers to multiple choice questions are evaluated as 1 and 0 point respectively. The data obtained from the open-ended questions were analyzed by using the analytical criteria developed by Temiz (2007). A comparison of the mean values of the points that students received from SPS test is presented in graph form. SPSS 15.0 Kruskall-Wallis H test has been used for the purpose of examining if there exists a statistically meaningful difference among the different grades in PST' SPS. Kruskall-Wallis H test, a non-parametric test, is used for the purpose of ranking data (Büyüköztürk, 2003). The data are presented in figures and tables.

Results

Findings of the data obtained from the assessing science process skills test for each module are given below.

Graph 1 presents a comparative display of the mean scores of answers given by PST at different grades to questions in module 1. As the graph shows, while PST at grade 1 score an average of 3.12 points, those at the 4th grade score an average of 3.7 points from module 1 questions.

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Identifying Variables and Formulating Hypotheses

Graph 1. Mean scores of answers given by PST at different grades to questions in module 1 "identifying variables and formulating hypotheses"

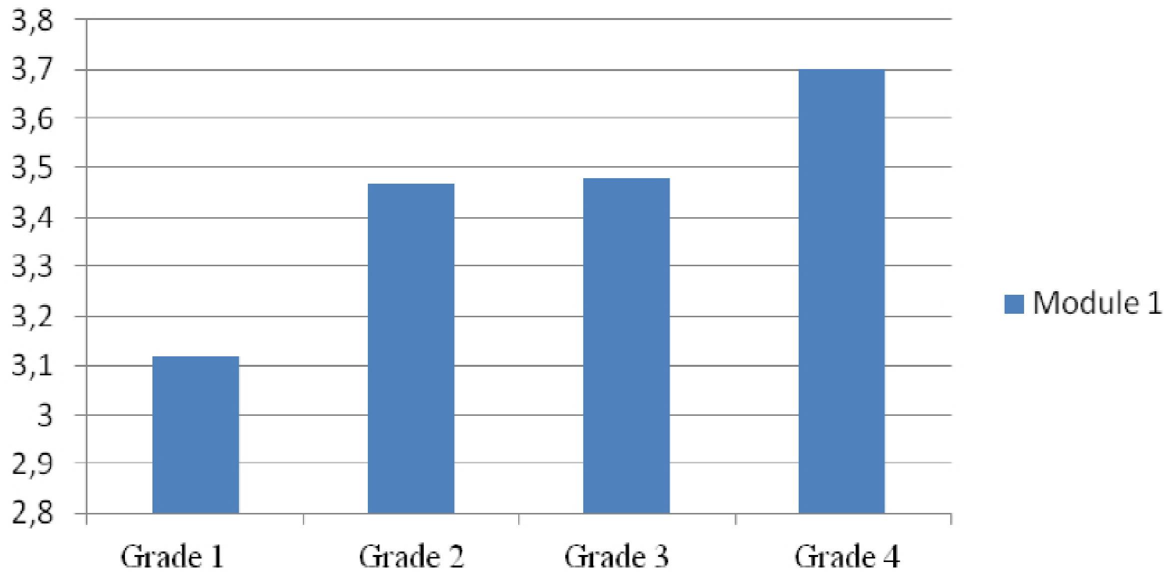

Table 1 Kruskall Wallis- H Test Results for Module 1

Comparing of SPS		N	Mean Rank	Sd	χ^2	P	Meaningful Differences
Module 1	Grade 1 (G1)	33	44.45	3	12.435	.006	G1< G2;
	Grade 2 (G2)	23	63.24				G2~ G3;
	Grade 3 (G3)	27	61.81				
	Grade 4 (G4)	34	68.01				G4> G1, G2, G3
	Total	117					

A comparison of mean scores of PST from different grades for module 1 shows that [(3) = 12.43, p< .05] it is possible to say that there is a meaningful difference. Although the comparison shows that there is no difference between the 2nd and the 3rd grades, it is possible to say that there is a continuous development from the 1 to the 4th grade.

Experimenting, Changing and Controlling Variables (Module 2)

Graph 2 is a comparative display of mean scores of answers given by PST at different grades to questions in module 2. As the graph shows, while PST at grade

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1 score an average of 0.54 points, those at grade 4th score an average of 0.67 points from module 2 questions.

Graph 2. Mean scores of answers given by PST at different grades to questions in module 2 "experimenting, changing and controlling variables"

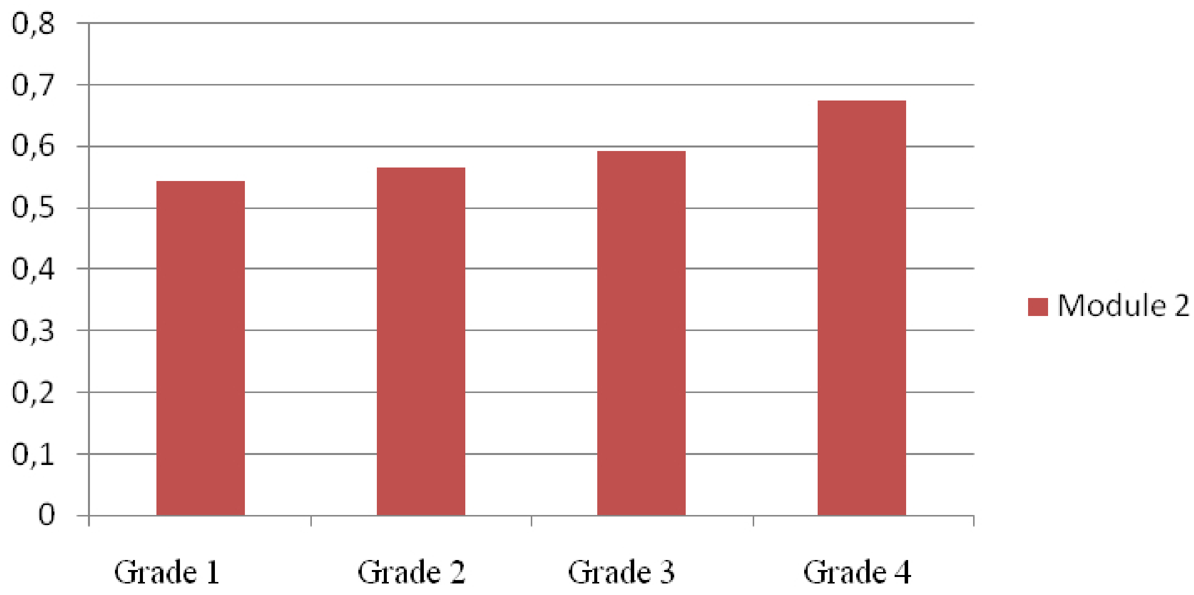

Table 2. Kruskall Wallis H Test Results for Module 2

Comparing of SPS		N	Mean Rank	sd	χ^2	P	Meaningful Differences
Module 2	Grade1(G1)	33	55.91	3	1.345	.719	G1~ G2 ~ G3~G4
	Grade2(G2)	23	57.07				
	Grade3(G3)	27	58.67				
	Grade4(G4)	34	63.57				
	Total	117					

Since a comparison of mean scores of PST from different grades for module 2 shows that [$X^2(3) = 1{,}345$, $p> .05$], there exists no meaningful difference. Although the comparison shows that there is no difference between the 1st, the 2nd and the 3rd grade, the mean score of the 4th grade is a bit higher than those of the rest.

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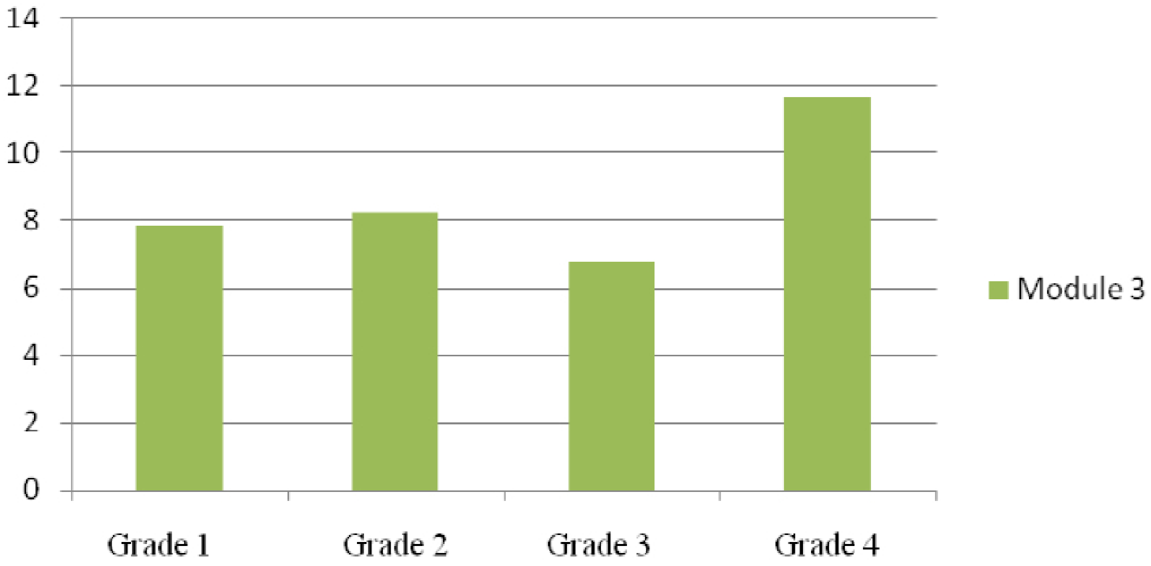
Collecting Data (Preparing Data Table)

Graph 3. Mean scores of answers given by PST at different grades to questions in module 3 “collecting data (preparing data table)”



Graph 3 comparatively displays mean scores of answers given by PST at different grades to questions in module 3. As the graph shows, while PST at grade 1 score an average of 7,84 points, 4th grade score an average of 11,65 points from module 3 questions.

Table 3. Kruskall Wallis H Test Results for Module 3

Comparing of SPS		N	Mean Rank	sd	χ^2	p	Meaningful Differences
Module 3	Grade 1 (G1)	33	47.00	3	33.184	.000	G1<G2;
	Grade 2 (G2)	23	51.07				G2>G3;
	Grade 3 (G3)	27	45.37				G3<G4;
	Grade 4 (G4)	34	86.84				G4> G1;
	Total	117					G4>G2.

Since a comparison of mean scores of PST from different grades for module 3 shows that $\chi^2(3) = 33.18$, $p< .05$], it is possible to say that there is a meaningful difference. It is also possible to say that PST’ mean scores except for grade 3 develop over the increasing grades.

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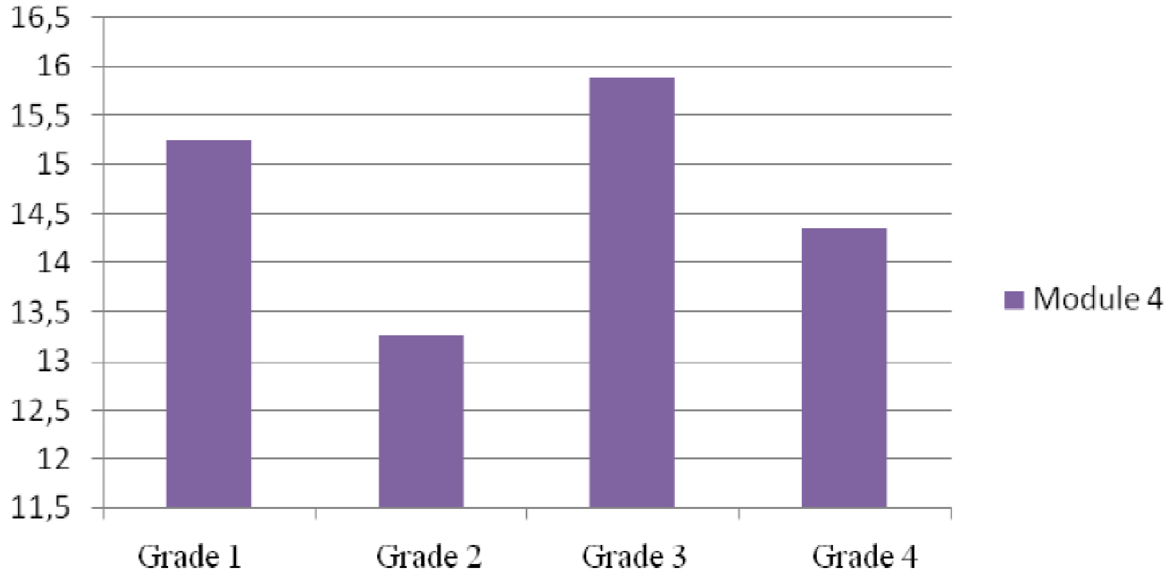
Drawing Graphs

Graph 4. Mean scores of answers given by PST at different grades to questions in module 4 "drawing graphs"



Graph 4 presents a comparative display of the mean scores of answers given by PST at different grades to questions in module 4. As the graph shows, while PST at grade 1 score an average of 15.24 points, 4th grade score an average of 14.35 points from module 4 questions.

Table 4. Kruskall Wallis H Test Results for Module 4

Comparing of SPS		N	Mean Rank	Sd	χ^2	p	Meaningful Differences
Module 4	Grade 1 (G1)	33	62.89	3	11.914	.008	G1>G2;
	Grade 2 (G2)	23	43.11				G2< G3;
	Grade 3 (G3)	27	74.30				G3> G4;
	Grade 4 (G4)	34	53.82				G1> G4;
	Total	117					G4> G2

Since a comparison of mean scores of PST from different grades for module 4 shows that [χ^2 (3) = 11.914, p< .05] it is possible to say that there is a meaningful difference. There is no steady increase in mean scores over the increasing grades, with the highest mean score belonging to third grade.

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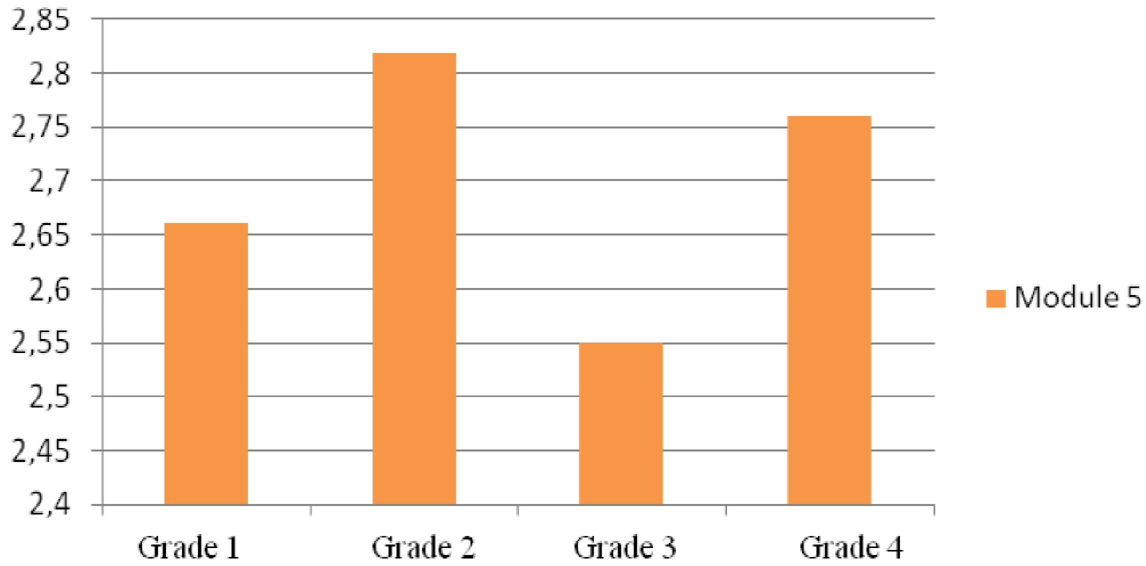
Interpreting Data (Interpreting Graphs)

Graph 5. Mean scores of answers given by PST at different grades to questions in module 5 "interpreting the data and reading graph"



Graph 5 presents a comparative display of the mean scores of answers given by PST at different grades to questions in module 5. As the graph shows, while PST at grade 1 score an average of 2.66 points, 2nd grade score an average of 2.82 and the 4th grade score an average of 2.76 points from module 4 questions.

Table 5. Kruskall Wallis H Test Results for Module 5

Comparing of SPS		N	Mean Rank	Sd	χ^2	p	Meaningful Differences
Module 5	Grade 1 (G1)	33	58.67	3	.782	.854	G1~ G2 ~ G3~G4
	Grade 2 (G2)	23	62.89				
	Grade 3 (G3)	27	54.98				
	Grade 4 (G4)	34	59.88				
	Total	117					

Since a comparison of mean scores of PST from different grades for module 5 shows that [χ^2 (3) = .782, p> .05], it is possible to say that there is no meaningful difference in PST' SPS. It is possible to say that the mean scores of PST from all grades are close to each other.

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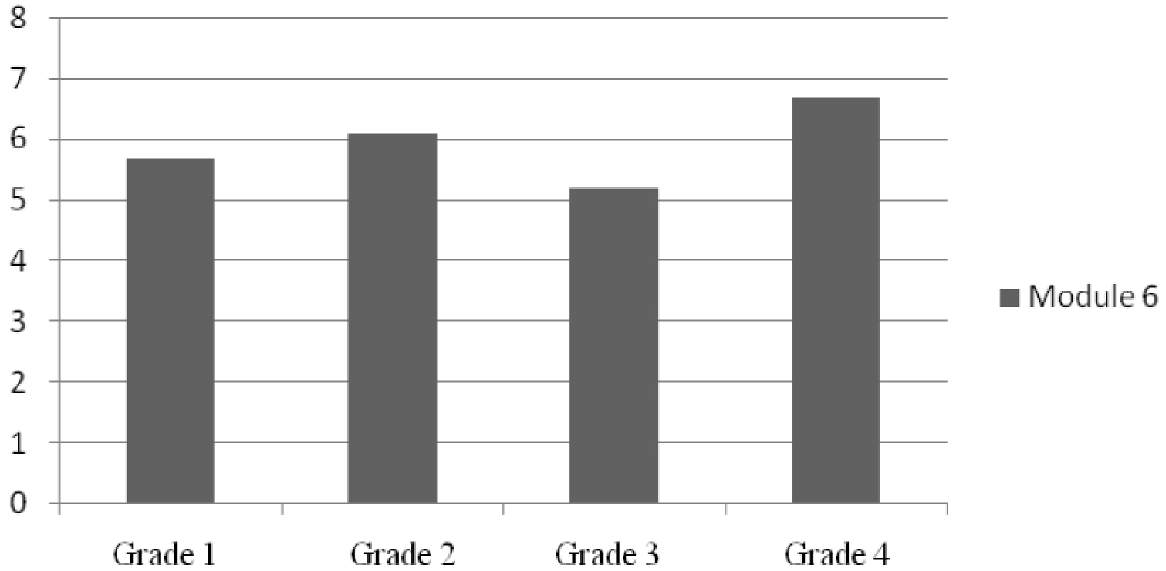
Identifying Variables and Formulating Hypotheses

Graph 6. Mean scores of answers given by PST at different grades to questions in module 6 "identifying variables and formulating hypotheses"



Graph 6 presents a comparative display of the mean scores of answers given by PST at different grades to questions in module 6. As the graph shows, while PST at grade 1 score an average of 5.7 points, 4th grade score an average of 6.7 points from module 6 questions.

Table 6. Kruskall Wallis-H Test Results for Module 6

Comparing of SPS		N	Mean Rank	Sd	χ^2	p	Meaningful Differences
Module 6	Grade 1 (G1)	33	55.38	3	10.036	.018	G1< G2;
	Grade 2 (G2)	23	61.72				G2> G3;
	Grade 3 (G3)	27	45.24				G4> G3;
	Grade 4 (G4)	34	71.60				G4> G1;
	Total	117					G4> G2

Since a comparison of mean scores of PST from different grades for module 6 shows that [χ^2 (3) = 10.036, p< .05], it is possible to say that there is a meaningful difference in PST' SPS. It is possible to say that there is steady development in scores from the first to the fourth grade except for grade 3.

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Discussion and Conclusion

The first graph enables us to make the interpretation that there seems to be a relationship between PST' grades and their ability to identify variables and make hypotheses. Findings from Kruskall Wallis H test show that there is a meaningful difference between PST' ability to 'identifying variables and formulating hypotheses'. The mean scores of groups increase over the increasing grades.

Findings from Kruskall Wallis H test shows that there is no meaningful difference between PST' ability to 'experiment, control and change variables'. That the group scores are close to each other could possibly be interpreted to mean grade is not a determinant variable of the skills of 'experimenting, changing and controlling variables'.

Kruskall Wallis H test results show that there is a meaningful difference in PST' skills of "collecting data, preparing data table". As the graph 3 shows, although the tendency is that group scores increase over the increasing grades, it is interesting that the grade 3 PST have the lowest mean score among all groups. The explanation for this might be that PST at grade 3, perhaps, have not had the relevant experience to develop adequately their skills of "collecting data, preparing data table" or that they are perhaps having problems with applying their skills. The latter possibility is in parallel to the finding of Farsakoğlu et al. (2008), that while PST can theoretically express SPS, they experience problem in application.

Kruskall Wallis H test results show that there is a meaningful difference among different grade groups in PST' skills of 'drawing graphs'. While a linear increase is expected in mean scores over the increasing grades, fourth grade students have scored lower than both the first and the third grades. The explanation for this situation may be that there is, perhaps, no relationship between the increasing grades and the skills of "drawing graphs".

A comparison of Kruskall Wallis H test results shows that there is no meaningful difference among groups in PST' skills of "interpreting data and reading graphs". It is possible to say that the mean scores of PST from different grades are very close. The interpretation might be that there is no relationship between increasing grades and the skills of "interpreting data and reading graphs".

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A comparison of groups in accordance with the Kruskall Wallis H test results shows that there is a meaningful difference in PST' skills of "identifying variables and formulating hypotheses". When there is an increasing tendency in the mean scores of PST over the increasing grades, there is a drop in the mean scores of third grade PST. This situation might be interpreted as no direct relationship existing between grades and the SPS of 'identifying variables and formulating hypotheses'.

SPS is obtained through experience, and individuals develop their skills through practice. Therefore, it is expected that PST develop their skills as they move along from grade 1 to grade 4. However, as this research shows there is no linear development for each SPS module. For modules 1, 3, 4 and 6, there is a meaningful difference in PST' SPS. For modules 1, 3 and 6, there is an increasing tendency from the first to the fourth grade. For module 4, however, the opposite applies. While the mean scores are very close to each other, there still exists a linear increase from the first to the fourth grade for module 2. Unsteady variations of mean scores attract attention for module 5.

In summary, all findings considered there seems to be no direct relationship between PST' grades and SPS. But it is expected that the SPS of well- equipped and qualified graduates who are PST will increase linear to a senior level.

When such as TIMSS and PISA studies were examined, it was seen that some questions measured students' SPS in these studies (ISC, 2000). However, what attracts attention are the very low rates for the correct answer to SPS-related questions in 1999, in participating countries in TIMSS (Bağcı Kılıç, 2003). Teachers have an important role and mission in results in this way. It is known that teachers can transfer to students their misconceptions (Valanides, 2000; Papageorgiou & Sakka, 2000). In this case, studies identifying teachers or prospective teachers' misconceptions and resolving them have become more important (Psillos & Kariotoglou, 1999; Taylor & Lucas, 2000; Parker & Heywood, 2000; McGregor & Gunter, 2006; Michail, Stamou & Stamou, 2007). In literature it is showed that teaching based on the SPS helps the PSTs both to improve their SPSs and achieve conceptual change together with removing their misconceptions (Nicosia et al, 1984; Dawson, 1999; Beaumont Walters and Soyibo, 2001; Kanlı, 2007; Karslı, 2011). In light of these researches, if teachers' SPS are developed, teachers can gain these skills to their students. Or they can encourage students to gain these skills. Besides, they may be more helpful on provide a positive conceptual change to the students.

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In this context, when the results of this study are also taken into consideration, prospective teachers, who will be responsible from preparing educational activities related to SPS in future, are required to be educated in such a way that they have SPS.

Suggestions

SPS is given importance in curriculum development and improvement studies (MNE, 2006). Therefore, students' acquisition of SPS is emphasized. In this respect, teachers have an important mission in developing students' SPS. For this to be possible, however, it is expected that primarily teachers should adopt and possess SPS.

Taking into consideration the finding that there is no relationship between SPS and grade levels, we have come to the view that it is having experience, not the grade level, which is important. Therefore, we suggest that PSTs are provided with environments in which they experience their SPS right from their grade onwards.

We also suggest that PSTs are provided with necessary feedback when they experience their SPS. This is because when PST answers to open ended questions were being assessed, it was seen that PST ignored some important issues such as 'putting titles above tables, indicating the units while drawing graphs, indicating the origin as (0,0) in graphs'. Therefore, it is very important that PSTs are given feedback while they are experiencing their SPS.

Some activities based on developing of SPS can be prepared and these activities can be implemented in their courses while learning of PST. In parallel, longitudinal research with the aim of following the development of prospective teachers' SPS should be done.

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