Experiences of Mathematics Student Teachers in a Series of Science Experiments

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Abstract: There is an increased interest in finding connections with mathematics and areas outside mathematics such as hard and soft sciences. This increased interest reflected in many of curriculum reforms that took place during the past few decades including the one in Turkish elementary and secondary mathematics education. Hence we believe that Turkish mathematics teachers should have the skills necessary for coping with the changing requirements of the 'new high school' mathematics'. Since research skills is an important requirement, the aim of the paper was chosen to be to investigate 32 mathematics student teachers' reactions during a series of physics experiment, which involves identification of the variables, measurement process and data analysis. In this case study, multi method approach is used in the study to get rich data for answering research questions. The main data collection tools are physics experiment lab reports. A categorization procedure was used to transform the mainly qualitative data into a statistically analyzable form. Findings indicate that student teachers' overall performances on the experiments were not satisfactory. Transforming formal mathematical knowledge into a physics experiment context was problematic. Main conclusion of the study is that teacher training curriculum currently used should be designed to equip the teachers the skills they need to cope with the changing requirements.

Key-Words: Mathematics Education, Teacher Training, Physics Experiments

1 Introduction

This study is part of a project supported by the Marmara University Research Fund in which because of lack of space, only the results of descriptive statistics will be discussed.

There is an increased interest in finding connections with mathematics and areas outside mathematics such as hard and soft sciences (e.g. astronomy, biology, chemistry, computer science, earth sciences, physics, economics, linguistics, political science, sociology/anthropology), professional life (e.g. architecture, business/industrial, trades, engineering, medicine) and humanities (e.g. art, literature, music). Mathematical tasks, emerge, from using such connections, it is argued, make the subject of mathematics not only more appealing and inspiring but also more "authentic" [9; 10; 13; 17]. It is argued that tasks that integrate mathematics and science can enhance students' understanding of and attitudes toward both mathematics and science [1]. Moreover, in order to make mathematical tasks less "dull, predictable, and routine..." [17] there is a strong case in the research and teaching literature to make the mathematics tasks less abstract and more real life based.

This increased tendency reflected in many of curriculum reforms that took place during the past few decades. For example, the initiator of the following curriculum changes in the UK was pointing to the importance of the idea of 'connections' by stating that the idea of investigation is fundamental both to the study of mathematics itself and to an understanding of the ways in which mathematics can be used to extend knowledge and to solve problems in very many fields [3]. NCTM's statements are also in paralleled with this opinion: It is stated that knowledge should merge from students' experience with real life problems [14] and that "thinking mathematically involves looking for connections, and making connections builds mathematical understanding" [15]. Integrated units of study should be fostered because "school mathematics experiences at all levels should include opportunities to learn about mathematics by working on problems arising in contexts outside of mathematics" [15].

The science education community has generally recognized the need for teachers of science to be competent in mathematics, but such a relation does not seem to exist between mathematics educators and science. It would be too much to ask to expect mathematics teachers competent in all areas of science, nevertheless, it is possible that mathematics teacher education programs can put more emphasis on developing the skills in using and applying mathematics in contexts outside mathematics.

Physics-related situations are common in the real-life problems. Physics being, "the description of the natural world by means of mathematics" [11] makes it a context of choice in designing authentic mathematical tasks. There is varying degree of complexity in tasks involving outside contexts which is related to the open vs. closed endedness of the task. This sometimes is a function of the number of mathematical concepts involved in the task or the embededness of the mathematical patterns hidden in the context.

2 Aim of the Study

A major curriculum reform is currently taking place in the Turkish national education system in elementary and secondary education. The proposed changes that are in line with the contemporary approaches on teaching and learning are being put into operation systematically. New reform proposes radical changes for the high school mathematics curriculum which traditionally prioritized algebraic thinking over using and applying mathematics [6]. The aim of mathematics teaching, as stated in the program document, is to apply the mathematical skills (problem solving, communication, reasoning, relational thinking) to the real life problems [12]. Hence we believe that Turkish mathematics teachers should have the skills necessary for coping with the changing requirements of the 'new high school' mathematics'.

Our major research tool is a series of science/physics experiments during which, we would like to observe how mathematics student teachers' performances change.

There are differences between the terms of 'real life (world) task', a mathematics word (world) problem and laboratory task, the common ground for all these is the use of outside mathematics contexts in varying degrees. However a lab experiment differs from a real life task in that it provides limitless number of trial and error (and intervention) opportunities but within a relatively poor in terms of contexts and materials, while observing a phenomenon. Nevertheless, it is possible that skills gathered in trials in an experiment can be carried out to other contexts.

We used three forms tasks sequentially, with increasing degree of student involvement (variation in the involvement of data production). We started with a 'pseudo-experiment' task, in which teacher produced data, is presented to the students. This is followed by a demonstration experiment in which the teacher is responsible for conducting the experiment (and producing data). In the final task students themselves are responsible for conducting the experiment.

Our aim, more specifically is to investigate prospective mathematics teachers' reactions during a series of experiments, which involves identifying the main and control variables in the given problem, taking measurements where necessary and analysis of the data obtained.

3 Methodology

This work was planned to be a case study as it tries to understand how a group of student teachers' experience during a series of experiments within a framework drawn by the researchers [4]. Multi method approach is used in the study to get rich data for answering research questions [4]. Because of the nature of the data, this research uses qualitative data collection tools. Data was obtained from 32 students trained in a three-semester mathematics teacher education program in Istanbul. The participants were mathematics student teachers with a B.Sc. degree in mathematics. After designing the appropriate research instruments, data was collected by administering all research instruments during the process of data collection to the designated sample in the university. The study uses a purposeful sampling [4; 16]. Categorizations and descriptive statistics were used to analyze the data.

In order to study student teachers' experimenting performances, we used a framework consisting of three consequent phases within each of which there were sub-phases: identification of research variables; process of measurement and process of data analysis. In the first phase "identification of research variables" student teachers were required to identify what are the dependent, independent and control variables from a given problem statement. The second phase, "process of measurement" only existed in the hands-on pendulum experiment in which students were observed to understand how well they perform during the core of the experiment process. The numerical data collected in this phase was number of measurements taken, number of trials within each measurement and number of pendulum swings during each trial. The third phase, "process of data analysis" consists of "predicting type of the relation", "use of data", "calculations", and "finding the equation". In "predicting type of the relation" stage student teachers, after plotting the data on a graph paper and before starting their calculations, were required to report their predictions to the instructor, who records them on a separate paper pairing with the names who made the predictions. "Use of data" refers to the method they choose in dealing with the data, e.g. how do they use their knowledge of statistics or if, instead of statistics, do they use only the formulas from analytical geometry course. "Calculations" refers to how well they perform while making their calculations. In the "finding the equation" stage we seek for data on how accurate their predictions made beforehand. In the whole process of experiment, student teachers were not given any directions on how to act. Only what was meant by the questions in the lab reports was explained. Guidance was provided only for students' technical difficulties. Otherwise they were completely alone.

3.1 Process of Data Collection

The main data collection tools in this study are experiment lab reports. Lab reports were prepared by the researchers with the collaboration from a university physics lab instructor for the three sequential experiments. Students' lab reports were analyzed in two ways. In the first method, qualitative data was quantified, i.e. students' answers in their lab reports were analyzed for the accuracy of their answers with a ready-made numerical categorization in which points were awarded for the correctness of the answers: 3 points were given for a full correct answers, 2 points were given for a partial correct answers, 1 point given for a wrong answer and 0 given if there is no answer. Second analysis is a closer analysis in which the search is for the information that could not be quantified.

Data was collected in the final weeks of the course on connections of mathematics with other disciplines. It was made sure that students have all the necessary knowledge (mainly statistics knowledge was the only prerequisite for the course)

There were three types of experiments that the students were required to conduct: the pseudo experiment, the demonstration experiment, and the hands on pendulum experiments.

Box 1. An example of a pseudo experiment question asked in the study [2]

The observed brightness of stars is classified by magnitude. The table shows how the difference d in magnitudes of two stars is related to the ratio of their brightness r. Comparing a first magnitude star with a sixth magnitude star, we have the magnitude difference $d = 6 - 1 = 5$, and we can see from the table that the first magnitude star appears 100 times as bright. Please complete the report according to the following data set

d	0	0.5	0.75	1.0	1.5	2	3	4	5	6	10	15
r	1	1.6	2	2.5	4	6.3	16	40	100	251	10^4	10^6

In the 'pseudo experiment' sets of ready-made experiment data were given with the lab reports. (one of the research questions was presented in Box.1)

Second type is the demonstration experiment that was conducted by the experimenter. The 'paper bridge' experiment (see Box. 2) was given to the students in which students are required to complete the lab reports after the lab instructor conducts the experiment.

Box 2. The 'paper bridge' experiment [5]

Question:
How is bridge thickness related to collapsing point
Materials:
Copier paper, paper clips, scissors, supports such as books or blocks of wood.
Procedure:
1. Three sheets of letter sized copier paper is cut in half length-wise to make 6 long strips of paper
2. Each end of paper is folded up 3cm (to add rigidity)
3. A bridge is made by 1 strip of paper with 2 books or other objects of similar height. The books are positioned 15 cm apart so that the paper bridge will span this distance. The paper strip is centered over the span with the folded ends points upward.
4. A paper clip is placed in the center of the bridge. This is continued until the bridge collapses. Number of clips are recorded in a table.
5. A second strip of paper is placed under the original strip to form a 2-layer bridge. Steps 2-4 are repeated.
6. Steps 2-5 are repeated using more layers of paper

The third type is the hands on pendulum experiment in which student teachers were randomly given one of the three different simple pendulum experiments all of which were drawn from the simple pendulum equation $T = 2Pi\sqrt{l/g}$ .and designed as three simple pendulum experiments. These were $T = f(l)$, $T = f(m)$ and $T = f(g)$.

3.2. Data Analysis

In the analysis of student teachers' responses, it was prominent to use a categorization to transform the mainly qualitative data into a statistically analyzable form. For this purpose, a qualitative categorization is used in which for a full correct answer a "3" is given, for a partial correct answer a "2" is given, for a wrong answer a "1" is given & a zero is given if there is no answer, in entering the data into the SPSS Package 10.0 program for statistical analyses.

The ensure the reliability of this categorization, (and the ratings given by the researchers), randomly chosen data was given to three other experts who were given information about the categorization beforehand. As a result of this, an average value of 72% of inter-rater agreement was obtained which is deemed sufficient.

4 Findings

In this section, results of the descriptive statistics are presented There are three main variables of the study whose results are shown in the table According to the statistical analyses, student teachers' scores seem to differ both with respect to the 4 variables and to the type of the experiment. The difference of performances due to the variables will be analyzed with the descriptive statistics. The results of the inferential statistics which show the differences due to the type of the experiment is not included in this paper because of the lack of space.

Table 1. Descriptive statistics: Student teachers' average scores on the experiments.

Variables	Pseudo Experiment		'Paper Bridge' experiment		Pendulum experiment		Average of the means
	Mean	SD	Mean	SD	Mean	SD	
1	Identification of research variables						
1.1.	2.69	0.74	2.88	0.42	3.00	0.00	2.86
1.2.	2.53	0.84	2.47	0.57	2.78	0.42	2.59
2	Process of measurement						
2.1.					2	0.95	
2.2.					5	2.49	
2.3.					5	1.31	
3.	Process of data analysis						
3.1.	2.13	1.10	2.41	1.04	2.25	1.08	2.26
3.2.	1.97	1.06	2.44	0.91	2.09	1.06	2.17
3.3.	1.56	0.95	2.09	0.69	1.63	0.99	2.76
3.4.	1.13	1.13	1.72	0.92	1.47	1.08	1.44

Variables whose numbers are given below are:
1.1. Identifying main variables
1.2. Identifying control variables
2.1. Number of measurements
2.2. Number of trials
2.3. Number of swings per trial
3.1. Predicting type of the relation
3.2. Use of data
3.3. Calculations
3.4. Finding the equation

The calculation of the responses for variables 1 & 3 was done with the following formula:
SCORE=1/N[(Number of correct answers) x 3 + (Number of partial correct answers) x 2 + (Number of wrong answers) x 1]

The table shows the descriptive statistics of participants' scores on the three experiments.

There is an observable gradual drop in overall performances starting from 1.1. to 3.4.. That is the highest overall performance is in "identifying main variables" (2.86), followed by "identifying control variables" (2.59), then by (2.26), then by "predicting type of the relation" (2.17), then by "use of data" (1.76). The lowest is "finding the equation" (1.44).

Student teachers seem to be successful in the interpretation of the main and control variables, although they performed worse in variable 2.2., "identifying control variables", in all three experiments. In variable 2, "process of measurement", student teachers' performances on the measurement tasks were reported. According to the table, during the pendulum experiment student teachers, on average, took 5 measures (e.g. at 5 values of the length variable), did two trials in each measure and let pendulum swing five times in each trial.

In variable 3 "process of data analysis" the gradual drop in performances continue. The accuracy in predicting the type of the relation (from the graphs they plotted) (var.3.1.) is the highest for the 'paper bridge' experiment and is the lowest for the pendulum experiment. This pattern repeats in the variables 3.2. (use of data), 3.3. (making calculations), 3.4. (finding the relation/equation), 4.1. (meaning of the limit) and 4.2. (meaning of the first derivative).

The analyses of student teachers' performances with respect to the three experiments reveal noteworthy findings. In 1.1. and 1.2., the highest performance is in the pendulum experiment (3.00 & 2.78 respectively) and the lowest performance is in the 'pseudo experiment' (2.69 & 2.53 respectively).

The highest accuracy in predicting the type of the relation is in the demonstration and the lowest is in the pseudo experiment (2.41 & 2.13 respectively). This pattern repeats in the 'use of data' (2.44 & 1.97 respectively), calculation (2.09 & 1.56 respectively) and 'finding the equation' (1.72 & 1.13 respectively) performances.

5 Discussion

In the discussion of the findings, we use two main sources. Quantitative data comes from the descriptive statistics. Qualitative data which comes from the in depth analysis of students' answers given in the lab reports was used to support the statistical data. It should be noted that the discussion of the findings is mainly based on students' overall performances in the three experiments rather than those in each of the three types of experiments.

There is a gradual drop of performances starting from the beginning to the end of the process, which is common for all three experiments. The first task student teachers face is the identification of main and control variables. This seems to be the easiest task in the whole process in all three experiments. Stating the dependent and independent variables of the given research problem needs a straightforward answer since these are often closely given in the problem statement. Data indicates that students are not very successful in identifying the control variables since these are often not stated explicitly in the lab reports or in the problem and that students are required to discover them from the context. In order to test whether their performance is reflected in practice, we need to look at how they perform in the process of measurement, which exists in the hands on pendulum experiment. Reduction of measurement errors is possible by controlling all the extraneous variables during the measurement process. In order to do this awareness of the experimenter of these factors is necessary but not sufficient.

One of the things for reducing the errors of measurement is to increase the number of measurements taken. In fact, our data suggested that the student teachers did not pay attention to take sufficient numbers of measurements (N=2). Similarly number of trials per measurement and number of pendulum swings per trial is not enough for the reliability of the data obtained (N=5 for both) considering the long time allowed for them to make the measurements. A very striking example took place in the pendulum experiment. One group that was doing the $T = f(l)$ experiment was asking why period obtained with *2l* length is greater that that with a *3l* length (l being a fixed length) for which contrary is the case. The reason was that the group did not enough measurements for the *2l* length.

This sloppiness in the measurement process might be one of the factors responsible for their low performances in the consequent process, i.e. the data analysis. The fact that the data students obtained during the measurement was not 'clean' enough may influence the performance in plotting the graphs. This seems to act as a 'snowball effect', influencing all consequent phases during the pendulum experiment. The fact that the drop of performance from 1.2. to 3.1. is the sharpest in the pendulum experiment compared to the other two (from 2.78 to 2.25) and that the pendulum experiment is the only one in which the students are actively engaged in data production clearly shows how influential measurement errors is in a science experiment.

Other factors should be responsible for the drop of performance observed in the pseudo and the demo experiment. For example students seem to show semi-satisfactory success in predicting the type of the graph from the given or produced data (2.13, 2.41 & 2.25 respectively i.e. partial correct answers were frequent). However their scores on "finding the equation" implies that they were not very successful in reaching to their predictions (1.13; 1.72 & 1.47 respectively, i.e. wrong answers were frequent). Since, except the pendulum experiment, data is provided beforehand, measurement errors could not solely be responsible for the performance drop. One other important factor that surfaced is the errors made during the calculation process. Our analysis reveals that these errors may stem from different reasons. First explanation we came up is students' inability to simplify big numbers during graph plotting. They certainly knew how to but did not seem to know how to apply this in plotting a graph. Closer analysis of students' lab reports indicated that simplifications were rarely used and calculations done with non-simplified numbers lead to calculation errors.

An example for was observed in a students' lab report of the pseudo experiment. In the question price change of a car from 2006 onwards was given and while plotting the data on the graph paper the student did not use any simplifications while it was possible, for example, to take 6 instead of 2006.

Another important finding pertains to some of the students' inaccuracy in predicting the type of the relation. For example, the analysis of students' answers on the lab reports indicated that considerable number of students predicted a linear relationship between the main variables even when there is no linearity. Data suggests three reasons for this: First is the insufficient number of measurement done in the measurement process (N=2 on average), which led to seeing the simplest form of relationship (i.e. linear) from the given data. Second reason is the inability to control the intervening variables resulting from the not showing enough care while doing measurements (e.g. in the pendulum experiment some of the students ignored to fix the angle from one measurement to the other which caused serious errors.). Moreover, students' predictions on the type of the relationship were also influenced by the mistaken appearance of the graphs drawn. Some wrong predictions seemed to be result of the improper scaling during data plotting on the graph papers.

6 Conclusions

Student teachers' performances on the experiments were not found satisfactory. This seems to be due to fact that their high school education was in the pre-reform period. There was inaccuracy in predictions, mistakes done during measurement and errors in calculations. The reason for the low performances is mostly related to the inability to use their basic measurement knowledge in the real or pseudo real situations. That is, most of the participants were not able to transform their formal mathematical knowledge into a science experiment context. This, we believe, is the result of the Turkish curriculum which is based on formal mathematics not giving emphasis on the applications of this knowledge.

Hence, to cope with the changing paradigm, teachers should have the necessary skills. Hence mathematics teacher training programs should be re-designed to adapt to the new high school curriculum.

In this respect, 'teacher as researcher' approach [8] is very important to change perspectives in teacher education system in particular and in society in general. However, school teachers who participated in the study still seem to understand the benefits for their professional developments and perceive it as a burden [7]. It is the duty of the faculties of education to train for teaching.

Experiments are the places learner should integrate mathematics, physics and daily life knowledge with their abilities. That is important in terms of new curriculum paradigm which is mostly based on constructivism in which learner should have an active role during the learning process, namely learners learn by doing.

References:

[1] Berlin, D. F., A Bibliography of Integrated Science and Mathematics Teaching and Learning Literature. *School Science and Mathematics Association Topics for Teacher Series (No. 6).* Bowling Green, OH: School Science and Mathematics Association, 1991

[2] Brown, R.G., *Advanced Mathematics: Pre-calculus with Discrete mathematics and Data Analysis*. Atlanta: Houghton Mifflin, 1992.

[3] Cockroft, W.H., *Mathematics Counts. Report of the Committee of Inquiry into the Teaching of Mathematics in Schools*, London: Her Majesty's Stationery Office, 1982.

[4] Cohen, L., Manion, L. and Morrison, K., *Research Methods in Education, (5th edition).* London: Routledge, 2000.

[5] Cothron, J.H., Giese, R.N. & Rezba, R.J. Science Experiments and Projects for Students: Fourth Edition. Kendall/Hunt Publishing Company, 2006.

[6] Delice, A. and Roper, T., 'Implications of a comparative study for mathematics education in the English education system'. *Teaching Mathematics and its Applications: An International Journal of the IMA,* Vol.25, No 2, 2006, pp.64-72.

[7] Delice A. & Aydin, E. The Influence of Student Teachers Research Orientation on their Professional Development (Öğretmen Adayının Araştırmacı Kimliğinin Mesleki Gelişimine Etkisi), *Paper presented on the Graduate Education Symposium (Lisansüstü Egitim Sempozyumu), İstanbul, 2005*

[8] Elliot; J., *Reconstructing teacher education-teacher development*, Falmer Press, 1993.

[9] Fairbairn, D. M. Creating story problems, *Arithmetic Teacher*, Vol 41,No 8, 1993, pp.140-142.

[10] Kilman, M., & Richards, J., Writing, sharing, and discussing mathematics stories. *Arithmetic Teacher,* Vol 40, No 3, 1992, pp.138-141.

[11] Korsunsky, B., Improper use of physics-related context in high school mathematics problems: Implications for learning and teaching**.** *School Science and Mathematics.* Vol 102, No 3; 2002, pp.107-113.

[12] Ministry of National Education. Department of Program Development. *High School Mathematics Program K12-K16*. Ankara, 2005 (T.C. Millî Eğitim Bakanlığı Talim ve Terbiye Kurulu Başkanlığı. Orta Öğretim 9.-12. Sınıflar Matematik Dersi Öğretim Programı. Ankara, 2005).

[13] Muth, K., Solving word problems: Middle school students and extraneous information. *School Science and Mathematics,* Vol 86, No 2, 1986, pp. 108-111.

[14] National Council of Teachers of Mathematics (NCTM). *Curriculum and Evaluation Standards for School Mathematics.* Reston/VA: National Council of Teachers of Mathematics Publications.

[15] National Council for Teachers of Mathematics. *Principles and Standards for School Mathematics*. Reston, VA:, 2000

[16] Patton, M. Q.., *Qualitative Evaluation and Research Methods* (2nd ed.). Newbury Park, Sage, Publication, 1990.

[17] Silverman, F. L., Winograd, K., & Strohauer, D. Student-generated story problems. *Arithmetic Teacher*, Vol 39, No 8, 1992, pp.6-12.