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The tendencies and difficulties experienced by pre-service science teachers during basic measuring

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Abstract

Besides the accuracy and reliability of the measuring tool, the other element that is required in this context is the basic knowledge, skills and competencies with which the individual making the measurement must be equipped. The present study aims to create awareness in third-year pre-service science teachers (n:75) about concepts of basic measurement (length, time, volume, mass and temperature) required in science/technology classes and to promote the development of related skills. Encompassing both quantitative and qualitative research techniques, the conclusion is drawn from data the whole measuring process is complex and the intentional and sustainable learning is required.

Keywords: Basic measuring; inquiry into measuring; cognitive skills; sensory skills; psychomotor skills; pre-service science teachers.

1. Introduction

Basic skills in measurement are a vital part of observation and the scientific method (Blomquist, 1993; Coelho & Sere, 1998; Hodson, 1988; Kuhn, 2008). Measurement is among the basic skills that all of us use in our daily life and in scientific research. The transfer of data between the individual and the object is achieved by means of a measuring instrument. Besides the accuracy and reliability of the measuring tool, the other element that is required in this context is the basic knowledge, skills and competencies with which the individual making the measurement must be equipped. Such skills described in three groups by Bloom: the first are cognitive skills where the concept to be measured in the individual is based on his/her learning of its theoretical background; the second are sensory (perceptive) skills arising from curiosity about what is to be measured; lastly are psychomotor skills that involve the use of the measuring tool. The development of these skills has a direct impact on the accuracy of the measurement.

There are limited studies, however, on measurement and developing measuring skills in science education that explain where the learners have difficulties (e.g., Hanley, Cammilleri, Tiger, & Ingvarsson, 2007). Most of the studies in literature focused on measurement hand-on activities for only children (e.g., Ashbrook, 2006; Callison, Anshutz, & Wright, 1997; Goldston, Marlette, & Pennington, 2001; Hand, 2005; Smith, Sterling, & Moyer-Packenham, 2006; Sterling, 2006) and since the whole process of measurement is complex and is usually considered

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to consume too much time during science teaching at school, the intentional and sustainable learning is most of the time missed.

Even though measurement is one of the prerequisite skills necessary for students to succeed in inquiry-oriented science class, it continues to be among the lowest trendy. This might be because teachers lack of knowledge and lack of adequate skills in using basic measurement devices. It is for this reason that the present study aims to create awareness in pre-service teacher about concepts of basic measurement (length, time, volume, mass, weight and temperature) required in science and technology classes and to promote the development of related skills. Moreover, this paper concerns the difficulties and obstacles encountered by students when handled a problem during the process of measurement.

2. Method

2.1. Participants

The study was conducted at a four-year public university located in the Mediterranean region of Turkey with seventy three (n=73) third years pre-service teachers enrolled in the department of Science Education in Primary School Teaching. The students were admitted to the college based on their scores on the nationwide, centralized university entrance exam and their preferences. Students of this department had already completed the basic physics, chemistry, biology and educational courses before the study was conducted.

2.2. Data Collection

The strategy for data collection in the study was determined on the basis of the cognitive, sensory and psychomotor skills used in measurement. Accordingly, a test of knowledge was used to establish what cognitive skills students used in measuring. The test was composed of four sections. The students in Section A were asked the open-ended question, “What is measurement used for in science?” The students in Section B were given pairs of questions and answers to match related to their ability to visually identify the measuring devices to be used in the exercise. Section C students were given a written test to determine whether or not they had used the specified basic measuring devices. Students in Section D were asked 10 true-false questions. Two of these questions were related to the nature of measurement, four had to do with measuring tools and their use and the remaining four questions explored the themes of sources of error, accuracy and consistency.

Various measuring devices were set up for the purpose of determining the students’ psychomotor skills. The objective of the setup was to trigger the students’ sense of curiosity and in this way prepare them for the activity. Six stations were set up, through which all students rotated, to measure various quantities and familiarize themselves with the devices as well as metric measurements. The six stations require students to: (1)Measure the length, internal and external diameter of a given test tube; (2) Measure the mass of several objects; (3) Measure the weight of several objects; (4) Measure the period of pendulum; (5) Measure the volume of a glass of water; (6) Measure the temperature of water.

The students decided themselves which measuring tool was necessary in each activity. At the conclusion of the pilot study, a skills observation form was created on the basis of the skills that were found to be guiding the students in their measuring. The form included the use of the basic measuring devices of a caliper, a ruler, a balance-type weighing scale, a dynamometer, a graded cylinder, a chronometer and a thermometer. The students were brought in one by one to the room where the setup had been prepared and their actions were videotaped. During the course of the activity, the students were watched by two observers and the results of the observations were recorded on the observation form. Both quantitative and qualitative research techniques were employed for data analysis. SPSS 14 was used for descriptive statistics.

Using all these strategies for data collection allowed reserachers to study aspects related to concepts as well as procedure, and to produce the analysis not only of the ‘saying’ but also of the ‘doing’.

3. Results (Findings)

The research findings were analyzed on the basis of cognitive and psychomotor skills.

3.1. Cognitive Skill

Section A of the test for knowledge encompassed the responses to the question asked of the students, “What is measurement used for in science?” The responses were: as a service to the future, to reduce margins of error, to attain reliability, accuracy, validity, consistency, permanence, decisive results, for provability, comparison, universality, numerical expression and analysis.

The results of the analysis for Section B showed that all of the students identified the form of the thermometer. In addition, most students were able to accurately pair up the names and the forms of the balance-type weighing scale, ruler, chronometer, dynamometer and graded cylinder. Only 30.1% of the students, however, were able to identify the caliper.

The results of the analysis for Section C revealed that all of the students used the ruler. The percentage of students stating that they used a thermometer, a chronometer, a graded cylinder and a weighing scale/balance was considerably high (~80%). Those who said they used the dynamometer comprised 57.5% of the students. With respect to the caliper, 37.0% of the students said they had never seen one, 23.3% stated that they had seen the tool but had never used it and 17.8% said that they had used one; 21.9% left the choices unmarked.

The table of data for the true-false and unanswered responses of the students on the themes in Section D is presented below (Table 1). The conclusion drawn was that students had a limited knowledge of the nature of measurement and about the subjects of margin of error, accuracy and consistency. With the exception of the caliper, 80% were able to indentify the measuring devices.

Table 1. Data for Test of Knowledge-Section D

Themes	Questions	Responses of True(%)	Responses of False(%)	Unmarked(%)
Nature of Measurement	All observations and experiments should be resolved through measurement.	35.6	46.6	17.8
	Measurement is only possible with a measuring tool.	23.3	65.8	10.9
Measuring Tools and their Use	When measuring with a dynamometer, the weight of the dynamometer changes the measurements.	11.0	60.3	28.7
	The tool that is used to measure time in called a chronometer.	89.0	8.2	2.8
	The tool that is used to accurately measure small volumes is called a caliper.	11.0	20.5	68.5
	Temperature, which is the average kinetic energy found in the center of mass of molecules of matter, is measured with a thermometer.	80.8	11.0	8.2
Sources of Error, Accuracy and Consistency in Measurement	You must use a 5 ml pipette to exactly measure fluid of 20 ml.	45.2	31.5	23.3
	Multiple measuring of a variable that has to be measured is not to be preferred because there will be differences between measurements.	6.8	75.4	17.8
	Even though the sources of error in a measurement may be known, they can never be eliminated .	28.7	60.3	11.0
	The use of a suitable measuring tool or method will dispose of any errors that may be made in measuring .	41.1	49.3	9.6

3.2. Psychomotor Skill

The codes devised for the skills students displayed in using measuring tools were based on their selection of the correct device and their correct use of that device. The recorded data indicates that the inter-rater reliability (IRR) ranged from 95% to 100% for individual items on the checklist.

The difficulties students encountered in terms of their skills were evaluated in six parts. The items included in the skills observation form for length measurement were the following: “*Was the caliper used for the outside diameter? Was the object held between the tips of the caliper? Was the caliper used for the inside diameter? Was the correct part of the caliper used for the inside diameter? Was a reading made on the caliper? Was a ruler used in* *height measurement? Was the caliper used in height measurement? Was the ruler set at zero before measuring*?" It was seen that approximately 50% of the students did not prefer to use a caliper and that those who did had difficulty opening the tips of the caliper or struggled to determine which part of the tool measured the inside diameter of the object. Students choosing to use a ruler for measuring height were in the majority (67.1%) and no difficulties were encountered in using the ruler.

The items included in the skills observation form for mass measurement were the following: "*Was the scale chosen? Was the scale properly balanced? Was the object placed in the center of the pan? Were the counterweights placed in the center of the pan? Were appropriate weights used? Were tweezers used?*" Of the students, 76.7% chose the balance for measuring mass but had difficulty in using it (only 27.4% were able to make the measurement). In addition, the students who used tweezers while measuring and put the counterweights in the middle of the pan were no more than 50% among the students who only were able to make the measurement.

The items included in the skills observation form for weight measurement were the following: "*Was the dynamometer chosen? Was the dynamometer hung at a fixed position? Was the measurement read at eye level? Was the object hooked onto the dynamometer?*" While 67.1% of the students chose to use the dynamometer in measuring weight, the remaining group made use of the weighing balance. Only two students out of the total (n=73, 2.7%) hung the dynamometer at a fixed position and took the measurement at eye level .

The items included in the skills observation form for the measurement of time were the following: "*Was the chronometer used? Was the chronometer started on time? Was the chronometer stopped on time? Were the buttons on the chronometer correctly used? Was an average taken for consistency?*" A percentage of 86.3% of the students used the chronometer. An average of 50% were able to properly start and stop the chronometer. There were only two students from the group, however, (n=73, 2.7%) who took the average of the values attained from multiple measurements of the period of the pendulum's swing.

The items included in the skills observation form for the measurement of volume were the following: "*Was the graded cylinder chosen for the measurement? Was the graded cylinder placed on a flat surface? Were the measurements read at eye level? Was care taken to obtain an exact measurement?*" Of the students, 76.7% chose to use the graded cylinder. There was no problem encountered in placing the device on a flat surface (82.2%) or in reading the measurement at eye level (61.6%) . However, only 24.7% of the students tried to obtain an exact measurement.

The items included in the skills observation form in the measurement of temperature were the following: "*Was the thermometer chosen? Was the bulb of the thermometer dipped into the liquid? Was care taken so that the thermometer did not touch the sides of the container? Was the thermometer read properly?*" While the majority of the students had no difficulty with using a thermometer, 30% dipped the bulbless end of the thermometer into the container in measuring the temperature of the water. One student tried to use a pipette instead of a thermometer for temperature measurement.

4. Discussion

The findings of the study showed that pre-service teachers were not equipped with adequate skills in using basic measurement devices. The results were paralel with the previous studies (e.g., Cepni, Kaya, & Kucuk, 2005; Costu, Ayas, Calık, Unal, & Karataş, 2005), however current study not only explored participants content knowledge of measurement but also observed their psychomotor skills and exposed where participants had difficulties. This is significant since the nature of measurement in science requires accuracy and consistency; one could not say that I know more or less measuring (Tretter, 2000). At the same time, it was established that measurement skills could be developed but that it would be necessary to sustain this development. If it is considered that measurement skills are an essential part of science, the deficiency of pre-service teachers in this area not only constitutes a major problem, but scientific knowledge structured around a lack of measurement skills signifies a poor foundation for science. In practical science laboratory classes, it is assumed that students have the necessary skills and therefore the class moves on to more advanced lessons, meaning that a pattern of deficient learning is constantly repeated. To prevent this, the measurement skills of pre-service teachers should be determined at the beginning of the school term, after which their deficiencies should be remedied, with this effort being continued throughout the academic term.

5. Conclusion and Recommendation

The conclusion is drawn from data the whole measuring process is complex and the intentional and sustainable learning is required. It is important that students engage in measurement activities that promote the development of a rich knowledge base, practice the procedures in using tools, and provide a variety of contexts for using the procedures and knowledge. All three elements provide a foundation for alter science learning and are essential to functioning in everyday life. For developing the measurement skills;

1- Establishing a series of stations where students demonstrate their skills in making measurements using real measuring tools is an effective teaching strategy for learning and assessing measurement skills. At each station have poster of guidance with picture of how to use the measuring devices. The process of making measurements usually helps students to clarify the conceptual differences between mass and weight; temperature and heat and etc.

2- The series of laboratory work and related activities should be take on for sustainable development of the measurement skills. Asking questions for struggling students to clarify their thinking such as “how do you know”, “what did you do to determine that?”, “do you think that is a good measurement? why?”

3- Measuring objects in other environments and different lessons is an other opportunity to extend instruction. For example outdoor activites observation. Inquiry into measuring can be use to optimize the positive impact. Understanding and enjoying measurement in a stimulating and challenging environment leads to the kind of problem solving, reasoning, communicating, and valuing of science and mathematics we would like to encourage throughout the entire curriculum.

4- Providing students with the opportunity to experience what it means to measure helps them to realize that measuring involves continuous those properties to a unit. Learning to measure is important because of the practicality and pervasiveness of measurement in our everyday life.

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