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An Activity-Based Study on Providing Basic Knowledge and Skills of Measurement in Teaching

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Abstract

Even though one of the prerequisites of inquiry-based science classes is acquiring measuring skills, there is not enough emphasis in the schools today on developing these skills. The current study, which has been designed with the thought that this situation may be caused by the fact that teachers do not have a sufficient level of measurement skills, aims to clarify knowledge of some basic quantities (length, mass, weight, volume, temperature and time), create awareness about fundamental skills in measuring related quantities, and develop these basic skills for the benefit of pre-service science teachers (n=73). The experimental study, which has been designed using a mixed research methodology, includes both qualitative and quantitative research methods, uses a skill-observation form and researcher observation notes, as well as pre-test, post-test and retention tests. This research, which focuses on developing measurement activities, reveals the importance of not only knowledge and skill integration but also of continuity in teaching measuring skills. In addition, recommendations have been set forth for the effective use of measurement tools in basic science education courses and some measurement activities have been suggested.

Key Words

Basic Measurement Concepts, Nature of Measurement, Measurement Skills, Use of Measurement Tools, and Measurement Activities.

Observation and experimentation, which form the basis of scientific study, gain meaning with measurement (Blomquist, 1993; Coelho & Sere, 1998; Hodson, 1988; Kuhn, 2008). In science, the foundation of proof lies in measurement (Baytaroğlu, Akkoyunlu, & Dizdar, 2008; European Association of National Metrology Institutes [Euramet], 2008; Koçaş, 2009). The process of measuring entails determining the quality and quantity to be measured, the selection of an appropriate measuring tool and measuring unit, the calculation of the margin of error that must be considered in the measurement and the decision on the accuracy and consistency of the measurement. The more meticulous the adherence to the steps in the measurement process, the closer the scientist gets to approaching accuracy in attaining knowledge (Beichner & Serway, 2000; Bueche & Jerde, 2000; Haliday & Resnick, 1997; Physical Sciences Study Committee [PSSC], 1966; TUBİTAK, 2010).

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Measuring in Physics and Science Education

The skills involved in the scientific process can be divided into two categories: the basic skills (observation, classification, scientific communication, *measurement*, prediction, reaching a conclusion) and combined skills (determining and controlling variables, setting and testing up a hypothesis, interpreting data, defining, experimentation and creating a model) (Bağcı-Kılıç, 2003). In elementary school programs in Turkey, the subject of measurement is limited to science and technology courses and mathematics classes. While the teaching of measurement is continuous in mathematics courses up until the 6th grade, this continuity does not exist in science and technology courses. The subject is only taught on the basis of three units in physics in the 9th and 10th grades in middle school (Milli Eğitim Bakanlığı [MEB], 2006, 2011).

Studies on Measurement Education

Measurement activities for pre-school children have been developed along the lines of Piaget's conservation tasks. Since pre-school children are not familiar with standard units, the activities were developed to allow them to compare measurements with sizes of objects they knew well (Ashbrook, 2006; Kamii & Clark, 1997; Long & Kamii, 2001; Parrot, 2005; Reece & Kamii, 2001).

In Grades 4-6 of elementary school, the activities that have been designed to develop students' knowledge and cognitive skills regarding measurement systems generally encompass the concepts of length, mass, temperature and volume (Coskie, 2007; Hand, 2005; Hanley, Cammilleri, Tiger, & Ingvarsson, 2007; Leyden, 1995; Sears, 2005; Sterling, 1999, 2006).

Up until the time students begin middle school, they are taught basic measurement topics. With the increased hours of laboratory classes scheduled in the middle school curriculum, students begin to have a pronounced need for basic measuring skills. Studies on the development of such skills, however, are limited (Coelho & Sere, 1998; Tretter, 2000).

A review of the studies carried out with teacher candidates and teachers on the topic of measurement reveal that students have not adequately developed the psychomotor skills needed for using measurement tools and equipment and that the conceptual foundation in this context is weak (Coştu, Ayas, Çalık, Ünal, & Karataş, 2005; Çepni, Kaya, & Küçük, 2005; Goldstone, Marlette, & Pennington, 2001).

Some researchers have considered the topic of measurement as part of the common domain of science and mathematics, stressing that measuring skills must be developed alongside of the skills achieved in both science and mathematics courses (Bloomquist, 1993; Callison, Anshutz, & Wright, 1997; Coskie, 2007; Hurley & Normandia, 2005; Leyden, 1995; Rommel-Esham, 2007; Sherman, 1997).

The failure to work on theory and practical application together in science education hinders integrated learning (Roth, 1994). The learning of measurement skills, however, necessitates both a theoretical framework and practical experience. It is for this reason that achieving basic measuring skills is fundamental to developing other higher level measuring skills (Oğuz, 2007).

Another important step to be taken in the measurement process is to master the use of measurement tools and equipment. Research has shown that inadequacies in the skills required in using tools and equipment become obstacles to reaching the desired outcome (Coştu et al., 2005; Çepni et al., 2005).

Purpose

The present study has sought to arouse awareness in science and technology teacher candidates about basic measuring skills and knowledge, aiming to provide a way of developing these skills and increasing teacher candidates' understanding of related concepts by creating activities using basic physical quantities of length, mass, weight, volume, temperature and time.

Materials and Method

Design

The research was of mixed-methodology design (Creswell, 1994) conducive to measuring both cognitive and psychomotor skills.

Research Population

The research population consisted of 73 teacher candidates in the third year of the Science Teaching Department of the Faculty of Education at a university in Western Turkey.

Data Collection Tools

A Monitoring Test and a Skills Observation Form developed by the researchers, as well as researcher notes, were used as data collection tools.

Monitoring Test: This was prepared by the researchers as a part of the cognitive dimension of the study, to determine the extent of students' cognitive skills with regard to measuring. Students were administered a pre-test, post-test and a test of retention. The questions asked were related to the nature of measurement, measurement tools and their use, sources of error in measurement, sensitivity and consistency.

Reliability of the Monitoring Test: This was carried out with an analysis of the items. Each item was evaluated in terms of a difficulty index and a corresponding discrimination index (Tuckman, 1999).

Skills Observation Form: A setup consisting of measuring tools was prepared to determine the extent of the students' psychomotor skills. Various tools for measuring length, mass, weight, volume, time and temperature were placed on a table in mixed order. These were a compass, a ruler, a measuring rod, a measuring tape, a set of balance scales, dynamometers of different sensitivities, a graduated cylinder and beaker, a dropper, pipette, chronometer and thermometer. The activities consisted of asking for measurements of the inner and outer diameter and length of a cylinder, the mass of a bottle stopper, the weight of an object, the period of a pendulum, the volume of a bottle of water, and the temperature of an amount of water. The students had to decide for themselves which measuring tool to use in each activity. The students were individually brought into the room where the setup had been arranged and their measuring was filmed with a video camera. They were also watched by two observers who noted their observations on the Skills Observation Forms. The inter-rater reliability value for the two observers varied between 95%-100%.

Researcher Notes: In the teaching dimension of the study, a setup station was arranged for basic measuring related to concepts of mass, weight, volume, length, temperature and time. The station served as an aid to teaching measurement and the correct use of measuring tools. After the teaching session, the next step was the implementation of an activity under the heading of "*The water-retention capacity of a sponge.*" A discussion was first held prior to the activity about how the water-retention capacity of a sponge could be found and each group was then allowed to carry on with their own method.

During the teaching process, the progress of the students was observed by the researchers and recorded in *"Researcher Notes 1."* To determine the use and level of progress of measuring skills, the students continued to be observed by the researchers following the completion of the instruction period. These observation notes were recorded in *"Researcher Notes 2."*

Data Analysis

In this study of mixed-methodology design, the total qualitative data collected with the monitoring test were analyzed using frequencies *(f)*, percentages *(%)*, and the one-way ANOVA for repeated measures. To determine the psychomotor skills, the data in the Skills Observation Form and the researcher notes were grouped by which measuring tools were selected and the themes related to their use. The items in the form were encoded in the data analysis. Camera recordings supported the analysis of the Skills Observation Form. In addition, a qualitative numerical analysis was carried out to associate themes and make forward estimations (Yıldırım & Şimşek, 2006).

Discussion

This section covers an analysis of the research results on a quantitative dimension based on the monitoring tests and on a qualitative dimension based on the Skills Observation Form and the interpretation of the researcher notes.

How Students Matched the Shapes of Measuring Tools with the Names of the Tools (Monitoring Test Section A)

In this section, it was determined whether students could identify measuring tools. Their ability to recognize these measurement tools was evaluated with a pre-test, post-test and a retention test. The results of these tests are summarized below.

Table 1.
Mean Values in the Pre-Test, Post-Test and Retention Test on Recognizing Measuring Tools

	Mean	Standard Deviation	N
Pre-test	79.6474	14.66176	73
Post-test	98.6297	4.23668	73
Retention test	95.0685	10.94472	73

A significant difference was found between the students' pre-test, post-test and retention test scores [$F_{(2\text{–}144)}$ = 72,480, p<.01]. The pre-test mean scores were significantly lower than the post-test and the retention test mean scores. This finding showed that students' knowledge about recognizing the shape of measuring tools had significantly increased after the instruction.

Table 2.
Single Factor ANOVA Results for Repeated Measures of Pre-Test, Post-Test and Retention Test Related to Recognizing Measuring Tools

Source of Variance	Sum of the Squares	ss	Squares Mean	F	p	Significant Difference
Intervention Group	10629,721	72	147,635			
Measurement	14863,353	2	7431,677	72,480	.000	2-1, 3-1, 2-3
Margin of Error	14764,930	144	102,534			
Total	40258,004	218				

1: Pre-test 2: Post-test 3: Retention test

Discussion on Recognizing Measuring Tools and Their Use

It was found out from the data obtained in the pre-test concerning recognizing the shape of measuring tools that a large portion of the students had no problem identifying the tools, with the exception of the compass, but that some students had difficulty telling the difference between a dynamometer and a simple pulley, a chronometer and a barometer, and a graduated cylinder and a beaker. As in some other studies, evidencing the importance of introducing measuring tools in measuring activities was also an outcome of the present study (Sterling, 1999, 2006; Hand, 2005; Sears, 2005).

In the post-test implemented after the instruction on measuring, it was observed that a large majority of the students were able to identify the measuring tools by their shapes and that this continued to be so in the retention test as well. However, some of the students who could not tell the difference between a graduated cylinder and a beaker were seen to make the same mistake in the retention test, even though they were able to identify the difference in the post-test. This suggested that some students were able to experience knowledge transfer in relatively short intervals but were unable to retain this information for a longer time (Osborne & Gilbert, 1980).

Knowledge of Measuring (Monitoring Test Section B)

The questions on knowledge of measuring were grouped around the themes, "*the nature of measurement*", "*measuring tools and their use*", "*sources of error in measuring*", and "*sensitivity and consistency.*" The data obtained on the knowledge of measuring were analyzed in terms of these themes. The results derived from the pre-test, post-test and retention test are presented below.

Table 3.
Mean Values for Pre-test, Post-test and Retention test on Knowledge of Measuring

	Mean	Standard Deviation	N
Pre-test	55.0685	14.44562	73
Post-test	83.0137	16.38808	73
Retention Test	854795	14.14617	73

Significant differences were found in the scores of the students' pre-test, post-test and retention tests [$F_{(2-144)}$ = 122.856, p<.01]. The mean pre-test scores were significantly lower than both the post-test mean score sand the mean scores on the retention test. On the other hand, no significant difference was seen between the scores of the post-test and the retention test. This finding suggests that students' knowledge about measuring increased significantly after the instruction. The fact that the results of the subsequent retention test were the same as the post-test indicated that the students had been able to retain their knowledge.

Discussion on Knowledge of Measuring

It was observed in the pre-test that students did not have adequate knowledge about the nature of measurement and that they tried to close up this gap in the post-test and retention test. The results showed, however, that it was not easy for the students to chan-

Table 4.
Single Factor ANOVA Results for Repeated Measures of Scores on Pre-Test, Post-Test and Retention Test for Knowledge of Measuring

Source of Variation	Sum of the Squares	ss	Mean Squares	F	p	Significant Difference
Intervention Group	24357.991	72	338.305			
Measurement	41654.795	2	20827.397	122.856	.000	2-1, 3-1
Error	24411.872	144	16.,527			
Total	90424,658	218				

1: Pre-test 2: Post-test 3: Retention test ge their already formed conceptions about the nature of measurement. Although it was seen that the misconceptions in the pre-test had been corrected to a great extent in the post-test, the retention test indicated that the misconceptions had been formed again, albeit with a little modification. This was similar to the difficulties experienced in recognizing measuring tools. Despite the fact that the new educational curriculum emphasizes the teaching of scientific thinking, the nature of science and scientific philosophy, students' skills in questioning and thinking scientifically are limited (De Jong & Van Joolingen, 1998; Klahr, 2000; Kuhn, Black, Kesselman, & Kaplan, 2000; Yürümezoğlu & Oğuz, 2008a, 2008b). This is also true in the case of students' comprehension of the nature of measurement. The skills related to a theoretical foundation need continuity and monitoring to develop (Aydoğdu, 2006; Bağcı-Kılıç, 2003; Wilke & Straits, 2005).

Discussion on the Results of Skills Observation

In the post-test and the retention test implemented subsequent to the instruction on measuring skills, it was seen that the level of students' knowledge about the measurement of time, temperature, mass and weight had increased. In the post-test, it was noted that students had difficulties with working with margins of error and writing down units of measurement in measuring volume and that this continued to hold true in the retention test as well. For measurements to be relayed to others and made comprehensible, units and error margins should be well defined (Altın, 2006). It is for this reason that writing down the measurement exactly is important. A numerical value in a measurement should include the margin of error and a unit of measurement. Lacking one or the other of these elements is enough to make the measurement worthless. Because of this, by the very nature of measurement, there is no such thing as deficient measurement (Benson, 1995; Beichner & Serway, 2000; Bueche & Jerde, 2000; Miller, 2005). The time devoted to having students practice their skills in writing down measurements must be increased and repeated exercises performed (Tretter, 2000; Parrot, 2005).

Discussion on Observations during and after the Instruction

An individual's ability to develop measuring skills, recognize measuring tools, use them in a practical manner, and understand the nature of measurement requires a certain accumulation of knowledge. Since the development of measuring skills is dependent upon the progress of an individual's cognitive, emotional and psychomotor skills, this constitutes a process over time (Callison et al., 1997; Çepni, Ayas, Johnson, & Turgut, 1997; Tretter, 2000).

Conclusion and Recommendations

The results obtained in this study show that measurement processes are complex but that they can be mastered with a purposeful and sustainable program of instruction. It is important for students to put the knowledge they have accumulated into practice by using tools and equipment and participating in measurement activities in a stimulating environment.

To develop measuring skills, a work station can be set up prior to laboratory lessons where a series of measurement activities can take place. In elementary school and middle school, an interdisciplinary approach may emphasize topics on the nature of measurement, measurement skills can be included among the topics taught in in-house training courses, and visual materials can be prepared for the implementation of measurement activities.

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