

## What is really measured: pre-service teachers' ideas about measurements in the physical sciences.

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### Abstract

*Modern measurement methods provide the broadest, most natural, least restricted bridge between the every day worlds of the laymen and the scientist. When students perceive topics they are studying to be relevant to their own world and to their own lives, motivation and interest generally increase. In this study, we explored pre-service science teachers' and general teachers' ideas and difficulties when they encounter measuring tools and measurement, since measuring is central to the experimental sciences. We explored their conceptual knowledge of measurement:*

- 1. what is really measured,*
- 2. does the instrument affect the measuring process and the system,*
- 3. reliability, "true" value, precision, accuracy, dispersion, error and uncertainty was examined.*

*We tried to surface their notions so that we will be able to strengthen their theoretical background and provide them with some strategies for use in the classroom. Future teachers need help to conceptualize where and how connections between the everyday world and science can be properly made. Measurement can provide accessible activities to illustrate historical, philosophical and cultural dimensions of science.*

### Introduction

The tools and techniques of measurements provide the most useful bridge between the every day worlds of the layman and of the specialist in science [3]. In their daily lives and concerns laymen are involved in the activities and the ideas of measurement. Gagne [2] included measuring among the skills needed to learn science and carry out experiments. Coelho and Sere [1] note that despite the centrality and the considerable conceptual activity that both precedes and follows the issue, insufficient time is given to discussing measurement in school. Lubben and Millar [4] report that many students aged 9-14 make measurements with no apparent awareness of the uncertainty associated with the measurement process or of the need to be able to defend their data as reliable.

Pre-service teachers need to consider students' conceptions in order to emphasize the notions of uniformity, validity, reliability and the suitability of various measuring tools in their future teaching.

Matthews [5] mentions the need to provide teachers with accessible case studies to illustrate the historical, philosophical and cultural dimensions of science and gives the example of Huygens' 1673 proposal of the second's pendulum as a universal standard of length. He argues that in order to be effective science teachers must be familiar with the concepts of science, understand the nature of science and its skills [5].

In this study we aimed to explore pre-service science and general teachers' ideas when they encounter measuring tools and measurement. Forty pre-service teachers took part in the framework of an introductory methodology course on science teaching.

### Research Design

Pre service science teachers and general teachers participating in an introductory science course took part in a study on the difficulties associated with measurement. Their initial ideas were elicited with a questionnaire. This was followed up by a recorded lesson, in which measuring the mass of carob seeds led them to consider important questions relating to measurements especially the confrontation with variability when trying to use a carob seed as a standard unit of mass (the ancients' carat). Manipulatives like measuring cylinders, thermometers and balances were used in the development and expansion of the measuring skills. There was also a discussion about whether measuring instruments measure what they purport to do, and if the measuring instruments interfere with the true value. The problems of spread, precision, accuracy and the true value of measurement were also considered.

### Results

Some of the issues that emerged from the initial questionnaire are presented.

In question one, participants were asked which quantities are measurable out of length, time, energy, heat, volume, density, speed, acceleration, force and electric current. Six of these quantities are readily recognized by the participants as measurable, where as energy, heat, density and acceleration can be calculated from indirect measurements.

To the second question, how can you find the magnitude of quantities that are not measurable? Only 40% gave a correct answer out of which only 3% gave a correct explanation and 28% did not explain. Typical

answers included “everything is measurable”, “every quantity has a suitable measuring instrument”, “by plugging into the equation”, “by indirect measurement” or “by estimation.”

To the third question, how do we know if the instrument is measuring what it is supposed to measure? Only 4 % gave a correct answer, 46 % gave incorrect answers explaining “the instrument is suited to the measuring the quantity”, “by comparing with previous measurements”, “if several measurements give a consistent value”, or “according to the measurement units.” There is little consideration of the kind of relationship between the quantity that is measured explicitly and the target quantity.

To the fourth question, what is the importance of uniformity in measurement? Forty four percentages gave a correct answer, 18 % explained correctly. This notion leads to the importance of standards as shown by the answers “everyone will use the same language every time and every where.”

Two situations were presented in the same questionnaire: a familiar one of a sick child (using thermometer), and an unfamiliar situation of using a device to measure the opacity of water. When comparing the two situations one student claimed the thermometer measures directly since the way it measures is more precise whereas using the opacity meter gives a general and indirect value. Others noted that “an accurate value indicates that the measured value is precise at a given moment in time”, or that “the opacity meter does not give a precise value because it is an observed value and everyone has a different way of looking”. There were many irrelevant answers that used pseudo-scientific catch-phrases, like: “we know the instrument is measuring what it is supposed to if the scaling is correct” or “if it is in working order” or “according to the result it gives” or “if the instrument gives a reasonable value” or “it is built for that purpose” or “if repeated measurement gives the same value.” Both situations require indirect measurement, most participants would use a thermometer to eliminate the personal bias measurement of touching the forehead as a person own temperature influences his or her perception of how warm a sick child feels. Opacity is subjective; no scale, however logical in concept or numerically well designed, can operate better than the performance of the substances whose changes it measures in response to variations in temperature or opacity.

## Conclusion

Practical obstacles face us when encountering variables (like temperature and opacity) which can not be measured directly in the sense that a meter-stick can measure length. Every indirect measurement device is obliged to measure changes in some other physical variable and then interpret or impute a value by means of a predetermined and some times arbitrary scale. Even direct measurement of length is some times doubtful, a problem which was not dealt in this study.

The practice of measurement procedures especially the confrontation with measurement reliability and variability( as with the carob seeds), led pre-service teachers to consider important questions relating to measurements, including the problems of validity, spread, precision, accuracy and true value. There is a need to strengthen the theoretical background of future teachers with the intricacies of measurement. We emphasized what promotes understanding rather than adeptness in calculations. Measurement can provide teachers with accessible case studies that can be utilised in classrooms to illustrate the historical, philosophical and cultural dimensions of science.

## References

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