



## Students' Perceptions of Physics Experimental Measurements

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**Abstract.** This study explored secondary Physics students' perceptions of measurement under the data collection, data processing and data set comparison phases of an experiment. The framework of the study was based on Allie *et al.* (1998) which classifies views of measurement as point paradigm or set paradigm. The point paradigm is characterized by a students' preference to merely choose a data point as representative value of a set of measurements. On the other hand, the set paradigm is exemplified by the computation of the average as the representative value of the set of measurements.

The most common perceptions of the students on measurement were probed using the modified Physics Measurement Questionnaire (PMQ). The extent of relationship between respondents' measurement perceptions across the three experimental phases with gender, and curriculum was explored using the Pearson r correlation.

It was found that the respondents were more likely to consistently favor the point paradigm when dealing with data collection and data processing tasks. Also, they manifested basic set views of measurement more than the deep set when comparing data sets. The respondents' perceptions of measurement under the three experimental phases were found to have low correlation between them, towards the respondents' gender and the curriculum.

The results of the study suggested a closer examination on how procedural knowledge is inculcated in the students' minds. It appeared that the students have vague understanding of how and why measurement should be performed in an experimental context. They need to learn to appreciate the significance of good measurements in science.

**Key word/s:** point paradigm; set paradigm; perception; Physics measurement; experimental phases

### 1. INTRODUCTION

Being a science secondary school teacher, allows one to observe and experience firsthand many things about the students and themselves. Mingling with students gives plenty of opportunities for teachers to assess their learning, how efficiently he/she has

delivered a lesson, what could have been factors that have affected the learning situation, and what could be done to improve it.

The current thrust in education points toward a community embracing science culture. This is where individuals are capable of resolving complex and even simple



problems in a scientific way and from a scientific perspective. They are also capable to design systematic and impartial methods in gathering information, researching, testing hypotheses and drawing out conclusions related to the problem at hand, among other things.

One specific and fundamental skill and knowledge inherent to scientific endeavours such as experiments is measurement. Proper measurements, correct recording of data and decision-making in terms of representation, accuracy and agreement between series of measurements boosts the acceptance of a discovery as well as hastens the expansion of knowledge either by replication or a variation of the discovery.

There are studies which have determined a gulf between the students' understanding and appreciation of underlying principles of physics laboratory measurements and their apparent ability to use formal aspects of data analysis (Sere et al, 1993) both in the school (Lubben and Millar, 1996; Coelho and Sere, 1998) and university (Evangelinos et al, 1999; Buffler et al 2001). Similarly, the current study attempted to gain insight on the students' perceptions of measurement.

## 2. METHODOLOGY

The participants in the study were 214 high school Physics students of Eastern Samar National Comprehensive High School. They were the top three classes under the Basic Education Curriculum (BEC) and the Revised Engineering and Science Education Program (RESEP).

The respondents' perceptions of measurement in three experimental phases were probed using the modified Physics Measurement Questionnaire (PMQ) by Allie *et al* (1998). The experimental phases were data collection, data processing and data set comparison phases. Data collection (DC) phase operationally refers to initial stages of an experiment when students are gathering

measurement data such as length and time. The data processing (DP) phase stresses on the students' perceptions on experimental processes such as using the measured data to plot a graph. Finally, data set comparison (DSC) phase deals with the students' assessment of sets of measurements' quality (accuracy) and agreement (spread).

There were three (3) probes designed to explore into the students' perceptions under the data collection phase. These were the *Repeating Distance measurements* (RD) probe, *Repeating Distance measurements Again* (RDA) probe and the *Repeating Time measurements* (RT) probe. Only the *Using Repeated* (UR) measurement and Straight Line Graph (SLG) probes were utilized for the data processing phase. Another two for data comparison phase, the Same Mean but Different Spread (SMDS) and Different Mean but Similar Spread (DMSS) probes, were integral in examining the students' perceptions of measurement. All the probes were deduced from a single experimental context. It described hypothetical experimenters facing experimental measurement dilemmas related to a projectile's (i.e. a marble) motion. Required measurement data were the total time the marble was suspended in air and the horizontal distance (i.e. range) it covered.

The PMQ classified the students' perceptions of measurement into either the point or the set paradigm. The *point paradigm* is exhibited by a student who for example only takes a single measurement and considers it as the correct "final answer" or measurement of a quantity. A *set thinker* on the other hand considers taking several measurements, computes for the average, and uses it to represent the series of values he gathered. (Buffler et al, 2001).

PMQ was administered toward the end of the school year when the students had performed a number of laboratory activities in their physics class. The PMQ perceptions were examined and assessed for *consistency* per



experimental phase as it was necessary in the analysis of data. This procedure will be elaborated in the following discussions. Class observations, interviews and essay compositions were obtained for triangulation of results.

Analysis of the students' responses to the PMQ probes was initially done by categorizing the responses into adhering to the set or the point paradigm using the PMQ Responses Coding Scheme. Then, for each of the 3 experimental phases, the respondent's answers were further classified, in terms of consistency, into consistent point (CP), consistent set (CS) or mixed (M) responses. Solely for the DC phase was an odd nominal scoring-system was followed to signify the level of consistency in students' responses since three (3) probes were given under this experimental phase. Kindly refer to Table 1.

Table 1. Guide in scoring PMQ responses

Data Collection Phase				
Classification	RD	RDA	RT	Score
Consistent Point Data Collector	Point	Point	Point	3
Mixed Point Data Collector	Point	Point	Set	5
Mixed Point Data Collector	Set	Point	Point	5
Mixed Point Data Collector	Point	Set	Point	5
Mixed Set Data Collector	Set	Set	Point	7
Mixed Set Data Collector	Point	Set	Set	7
Mixed Set Data Collector	Set	Point	Set	7
Consistent Set Data Collector	Set	Set	Set	9
Data Processing Phase				
Classification	UR	SLG	Score	
Consistent Point Data Processor	Point	Point	2	
Mixed Data Processor	Set	Point	4	

Mixed Data Processor	Point	Set	4
Consistent Set Data Processor	Set	Set	6
Data Set Comparison Phase			
Classification	SMDS	DMSS	Score
Consistent Basic Set Data Comparer	Point	Point	2
Mixed Comparer	Set	Point	4
Mixed Comparer	Point	Set	4
Consistent Set Comparer	Set	Set	6

A score of three (3) was utilized to indicate consistent point paradigm adherence or that the student exhibited the point reasoning based on his responses to the three (3) probes under the experimental phase. Students responses categorized under mixed point data collector (MP DC) were numerically-labeled as five (5) if two of the three probe responses revealed point reasoning. Correspondingly, mixed set data collectors (MS DC) were those students with responses nominally-scored with seven (7). That is, they responded using the point paradigm on just a single DC probe. Finally, a score of nine (9) denotes consistent set thinking. Meanwhile, an even nominal scoring-system was pursued for the experimental phases with only two probes, the DP and DSC phases. That is, if a student's responses consistently showed preference for the point paradigm (or the basic set paradigm) in his responses to the two probes under the experimental phase, a nominal score of two (2) was given. When the responses exhibited consistent set (or consistent deep set) thinking, it was scored as six (6). If response to one probe revealed point reasoning and set reasoning on the other probe (or basic set on one probe and deep set on the other), then, a nominal score of four (4) was ascribed. Note that, unlike the DC and DP probes, the DSC probes classified the responses into either the basic or the deep set reasoning. This is

because hints of an average measurement which is inherent of the set paradigm were indicated *a priori* in the probes.

In general, higher nominal scores were designated to student responses revealing ideas closer to the (deep) set paradigm. These scores were the values entered in the computation of the Pearson *r* correlation coefficient.

### 3. RESULTS AND DISCUSSION

It must be noted that in the following discussions, the total number of respondents considered varies. This stems from the variable number of not classified (NC) responses per probe. Consequently, the total of responses taken into account per experimental phase differed in the analysis of students' perceptions per experimental phase and across experimental phases.

#### A. Point paradigm versus set paradigm

##### Data collection (DC) phase

The chart below (Figure 1) illustrates the distribution of students' responses to the DC probes. It was found that 61% (79 of 129) of the respondents consistently used the point paradigm. These students considered the result of a single measurement as the correct data. Hence, they are not likely to repeat the measurement. For them repetition of measurement is mostly to verify the measurement's correctness or find an equal or a recurring value which they will consider as the final correct answer.

Twenty-seven students (21%) believed that the final answer is obtained from the average of several measurements. Twenty-three (17%) mixed data collectors were also identified. These students shifted paradigms as they answered the probes in the PMQ.

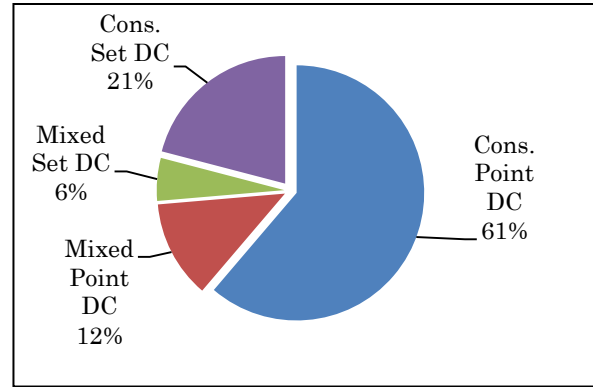


Figure 1. Distribution of responses per data collection classification

Nonetheless, it has to be noted that more than half of this mixed paradigm thinkers shifted to the set paradigm only when they answered the RT probe. It is the last to be presented among the three probes under the DC phase. Also, it provided a hint of the set paradigm by the mention of the concept of averages. This somehow indicated that the respondents were only reminded to get the average that is why they were able to respond to the RT probe along the set paradigm. They need prompts or they need to be instructed to get the average from several measurement repeats otherwise, they will stick to the initial or the most recurring value.

##### Data processing (DP) phase

The data processing probes are the UR measurement and SLG probe which explores the students' views on how they process and represent a series of measurements in numerical and graphical forms. Figure 2 shows the percentage of responses.

An important finding was that none of the students were found to consistently use the set paradigm when processing data. Most of them instead consistently used the point paradigm forming 54% (93 of 172) of the respondents. A large portion of these 93 respondents consistently chose the most recurring value and represented a series of

plotted data points with a zigzag line (connect-the-dot). The remaining 46% (79 of 172) were shown to use mixed paradigms when

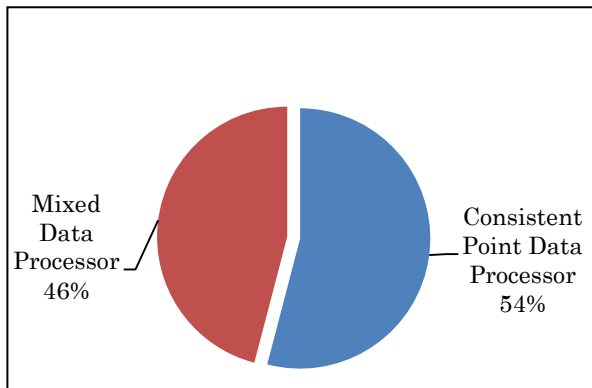


Figure 2. Distribution of responses per DP classification

answering the DP probes. All of them answered the UR probe using the set paradigm and shifted to the point paradigm in answering the SLG probe. They appeared to be unable to carry over their understanding of measurements and how it should be represented numerically to a situation where they were required to represent the series of measurements in a graph.

### Data comparison phase

The students' perceptions of measurement under the DSC phase of an experiment were revealed in the SMDS and the DMSS probes. The probes' context present the concept of an average value *a priori* which is inherent in the set paradigm. Thus, the responses were categorized into the consistent basic set (CBS) response, the consistent deep set (CDS) response and mixed set (MS) response.

As shown in Figure 3, it was found that 78% of the respondents consistently used the basic set paradigm when comparing two

data sets to decide which is better or if the results in the sets agree. These respondents only considered the mean which was already given in the probe in evaluating the quality and the agreement between the two sets of data and disregarded the spread of the results.

There was however, one respondent who constantly gave out deep set responses. That is, she considered and looked into not just the mean but also the spread of the results in deciding which was better between the two given data sets and whether the data in each of the sets were consistent.

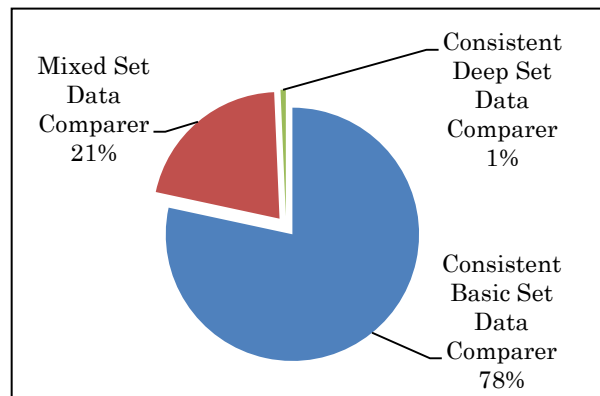


Figure 3. Distribution of responses per DSC classification

It was also found that 31 respondents had mixed perceptions of the data comparison tasks in an experiment. All of them were found to have considered the mean and the spread in answering the SMDS probe but not when they answered the DMSS probe. It must be mentioned that the concept of the spread was explicitly mentioned in the SMDS probe but not in the DMSS probe. It appeared that they only examined the given average values. Without the prompts, majority did not realize the significance of the overlapping spread of the results.



### B. Correlation of perceptions between experimental phases

There is a low correlation (0.49) between the students' perceptions of measurement in the Data Collection phase and in the Data Processing phase. And practically an extremely low correlation (0.16) between the students' perceptions of measurement in the Data Collection phase and in the Data Set Comparison phase. See Figs. 4 & 5.

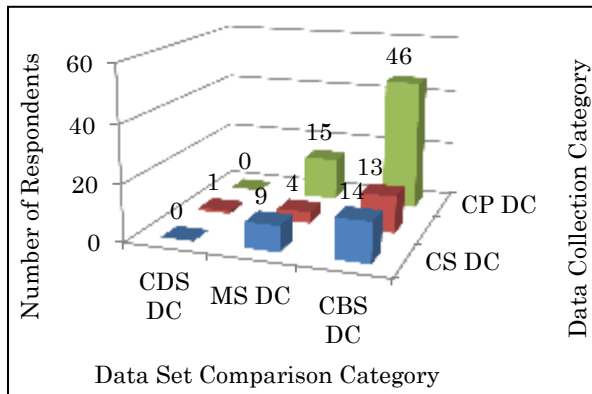


Figure 4. Cross-classification of respondents between DC and DP phases

There were no indications that the paradigms of the respondents vary under different experimental phases. In fact, looking into the total number of respondents cross-classified into the response categories for DC and DP phases, it can be seen that on both experimental phases, the greatest concentration of responses were towards the consistent point paradigm categories. Furthermore, for the DC responses the greatest number of responses revealed mixed paradigms. Furthermore, there is an equal number of responses in the consistent point and consistent set paradigm categories under the DP phase, thus resulting to the low correlation.

The same can be said of the respondents' perceptions of measurement under the DC phase correlated to those for DSC phase. There was very low correlation at 0.34 which was evident by the very small variation in the number of consistent deep set data comparers while the frequency of responses under the DC phase changes.

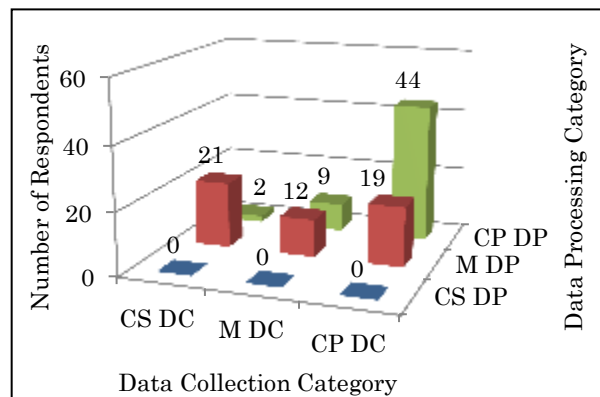


Figure 5. Cross-classification of respondents between DC and DSC phases

### C. Correlation between perceptions of measurement and gender

It was found that there is practically no correlation between the students' measurement paradigm and gender. Students' perceptions of measurement in the DC, DP and DSC phases did not vary among male and female respondents. Both used most consistently the point paradigm than the set paradigm. None of the respondents exhibited a consistent (deep) set thinking for the data processing and data set comparison phases whereas in the DC phase probes, less than half of the consistent point data collectors (CP DC), at 47.8% and 28.6% were found to be consistent set thinkers among the male and female respondents, respectively.

### D. Correlation between perceptions of measurement and curriculum



The students' paradigms in the three experimental phases and curriculum (RESEP and BEC) yielded low correlations at 0.48, 0.37 and 0.13. This implied that curriculum is not an indicator of their paradigm preference (point or set).

#### 4. CONCLUSIONS

The mostly used measurement paradigm of the respondents in the three experimental phases was found to be the point paradigm. Majority of the respondents were inclined to take only a single measurement and if they do, it was only to verify the presumed "correctness" of the initial value read. Also, in the data processing phase, the respondents were found to engage into measurement tasks using consistently the point paradigm. A large part of the respondents opted to write the most recurring value of a series of measurement data as their final answer and represented their data in a graph by connecting the plotted points instead finding the line of best fit. When the concept of average and the spread were presented in the data comparison probes, the respondents generally still referred to just the mean when comparing the quality and the agreement between two sets of five measurement values. They expressed the idea that two data sets are equally good because they have the same average value even if one has greater range or spread. Also, they believed that two data sets do not agree based merely on the presented unequal averages without considering the overlap of the spread.

Interestingly, it was found that the paradigm the respondents are likely to use when processing or comparing data set is independent of the paradigm they employ when collecting data. They tend to address each experimental phase separately.

Finally, the respondents' paradigm preferences in measurement were found to have low correlation with gender and the curriculum.

#### 5. ACKNOWLEDGEMENT

This study was funded by the Philippine Department of Science and Technology- Science Education Institute (DOST-SEI) through the Accelerated Science, Technology, and Human Resource Development Program.

We would also like to thank the faculty and personnel of ESNCHS, the research site.

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Presented at the DLSU Research Congress 2014  
De La Salle University, Manila, Philippines

March 6-8, 2014

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