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An investigation into senior high school three (shs3) physics students understanding of measurement uncertainty of length and time of scientitfic measurement in the Volta region of Ghana

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ABSTRACT

Physical quantity is a topic in the elective physics syllabus in taught in all categories of senior high schools two (SHS2) in Ghana and science students are to show an appreciable understanding of its measurement. However, serious doubt have been raised in the Physics Chief Examiner's report of the West African Examination Council of Ghana of both physics-1 (theory) and physics-2 (practical) as to whether science students really understand measurement of physical quantities. In view of this, the researcher used a mixed designed method to gather data from SHS3 physics students' on their understanding of measurement uncertainty of length and time. A population of 422 SHS3 physics students were sampled and a two item questionnaire on distance and time administered in order to find out whether the problem enumerated by the Chief Examiners' of Physics concerning physics students exist and were either with the set paradigm or the point paradigm concept. Also five SHS3 physics were purposively selected and interviewed in order to validate students' written responses. The study revealed that students do not have an understanding of measurement uncertainty by the set paradigm concept. Based on the findings of this study it was recommended that physics teachers should make effort to make scientific measurement by the set paradigm concept relevant to all senior high school science students in Volta region of Ghana.

Introduction

Accuracy and precision are synonyms (Wilson, 2009; Thomson, 1997). To most scientists' accuracy and precision, however, are two distinct concepts, even though the two are closely related. When a measurement of a physical quantity is accurate, it means that the said measured physical quantity is very near or close to the 'true' value. This true value may either be on the side of set paradigm concept or point paradigm concept (Allie, Buffler, Campbell & Lubben 2003). And when a measurement of a quantity is precise, it means the said measured physical quantity is very reproducible (Wilson, 2009; Thomson, 1997). The phrase very has been used by Wilson, (2009) and Thomson, (1997) to depict the degree to which measurement of physical quantity can be repeated or replicated.

Physical quantity is a topic in the elective physics syllabus in taught in all categories of senior high schools (Ghana Education Service, 2009) two (SHS2) in Ghana and science students are to show an appreciable understanding of its measurement (physics syllabus, 2007). Scientists and engineers routinely use physical quantities to represent the measured properties of physical objects. Some mathematicians have studied physical quantities from a more abstract standpoint, with the aim of better understanding the nature and use of those quantities (Sharlow, 2009).

Experimentation and measurement are fundamental to knowledge production in both the applied and natural sciences, including technology. Meaningful engagement by students in scientific activities that are experimentally based requires an understanding of science concepts for the procedures that are followed (Allie, Buffler, Campbell & Lubben, 2001). However, most science students in senior high schools in Ghana find difficulty in understanding measurement of physical quantities, the physics Chief Examiner's report of the West African Examination Council (WAEC, 2000, 2002, & 2006). Other countries such as USA, Australia, Denmark, Sweden and South Africa (Allie et al, 2003; Deardorff, 2001; Lippmann, 2003) also faced similar problems with their science students as has already been indicated by the physics Chief Examiner's report of the West African Examination Council (WAEC, 2000, 2002, & 2006). Due to this, the researcher deems it right to carryout an investigation into physics students' understanding of measurement uncertainty of length and time in category A, category B, category C, and category D senior high schools in the Volta region of Ghana (Ghana Education Service, 2009).

Statement of the Problem

Although practical work forms part of the senior high school physics curricula in Ghana (physics syllabus, 2007), it is not clear as to the level at which senior high school physics students in category A, category B, category C, and category D senior high schools in the Volta region of Ghana understand the basic ideas of measurement of physical quantities and the appropriateness of the data treatment procedures that they learn to use (WAEC, 2000, 2002 and 2006). All what is usually expected is that after the senior high school physics laboratory course, physics students should able to use an array of data analysis techniques, such as calculating the mean, standard deviation of the mean of physical quantities (physics syllabus,

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2007) but not the understanding of the concepts of measurement (Anamuah-Mensah, Mensah, & Otuka, 2001).

Also serious doubt have been raised in the Physics Chief Examiner's report of the West African Examination Council of Ghana (WAEC, 2000, 2002 and 2006) of both physics-1 (theory) and physics-2 (practical) as to whether science students really understand measurement uncertainty of physical quantities. For example the November / December, 2000 Chief Examiner's report of Physics indicated that many science candidates made deductions after obtaining only one reading from their experiments.

The one deduction made by the science students after obtaining one result from their practical examination, that is physics-2 (practical) examination as reported by the Physics Chief Examiner's report of the West African Examination Council of Ghana (WAEC, 2000, 2002 and 2006) was in line with the point paradigm concept of measurement i.e. the point paradigm concept is characterized by the underlying notion that each measurement could in principle be the true value (Allie, Buffler, Campbell & Lubben, 2005).

However, while the Physics Syllabus of Ghana for senior high schools and some researches in pure sciences, applied science and science education strongly subscribed to the use of the set paradigm concept (i.e. all available data are used to construct distributions from which the best approximation of the scientist and an interval of uncertainty are derived) by science students and scientist the world over (Allie et al, 2003; Bassarath & Whiteley, 2009; International Organization for Standardization (ISO), 2003; Physics Syllabus, 2007) when it come to measurement of physical quantity, yet many science students in Ghana still made deductions after taken one measurement (WAEC, 2000).

The July/August, 2002 and 2006 Physics Chief Examiner's reports revealed further that, many science candidates did not repeat experimental readings so that two sets of values could be obtained and a mean taken. This implies that the Physics Chief Examiner's reports of 2002 and 2006 expected science students to repeat their experimental readings so that two or more sets of data can be obtained for the calculation of mean (average). This assertion is in line with the set paradigm concept of measurement of physical quantities where by experiments are to be repeated to get means, standard deviation of the mean and variance of the mean (Allie et al, 2001) in order to reduce or minimize random errors or any other errors aside random errors in measurement of physical quantities. This is because, one experiment cannot give the 'true value', unless that experiment is performed several times, and the mean of the numerous data collected is estimated to eliminate uncertainties in measured results (Bassarath & Whiteley, 2009).

These lapses enumerated by the Physics Chief Examiner's report of the West African Examination Council of Ghana (WAEC, 2000, 2002 and 2006) of both physics-1 (theory) and physics-2 (practical) could either be due to anxiety of physics students during the examination or the type of examination questions set by the West Africa Examination Council or the lack of understanding of measurement of physical quantities or the holding onto either the set paradigm concept or the point paradigm concept or the mixed paradigm by some science students or the students own conception.

It is therefore worthwhile to investigate into physics students understanding of measurement uncertainty of length and time in SHS3 in category A, category B, category C, and category D senior high schools in the Volta region in order to understand the causes of these confusion and misunderstanding by science students so that instruction on this subject can be improved.

Purpose of the Study

The purpose of this study is to;

Explore SHS3 physics students' understanding of measurement uncertainty of length and time in category A, category B, category C, and category D senior high schools in the Volta region.

Research Question

This study will attempt to answer the following research questions of length and time.

What is SHS3 physics students' understanding of measurement uncertainty of length and time in category A, category B, category C, and category D senior high schools in the Volta region?

Delimitation

This study used only SHS3 physics students in data collection of length and time; this was because, by the time the physics students from SHS2 get to SHS3 in their various schools, they might have been taught measurement of physical quantities as has been specified in the physics syllabus, 2007. Thus, SHS3 physics students would be in the best position to respond meaningfully to the closed and opened ended questionnaire items and structured interview items of the study.

This study also considered only length and time aspect of measurement of physical quantities. This was because, these two physical quantities i.e. length and time, are fundamental quantities and also it form daily measurements that students undertake either in their schools or homes.

This study also considered only the understanding of SHS3 physics students in measurement uncertainty of length and time.

Limitation

Some of the students were absent on the agreed day for the administration of the closed and opened ended questionnaire item in the rest of the selected category of schools.

Review of Related Literature

Measurement Uncertainty

Uncertainty of measurement is the doubt that exists about the result of any measurement. For example one might think that well-made rulers, clocks and thermometers should be trustworthy, and thus give the right answers. But for every measurement even with the most careful ones, there is always a margin of doubt (Bell, 1999).

Measurement Uncertainty is a parameter that is associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand (Deardorff, 2001; Allie et al, 2005; International Union of Pure and Applied Chemistry (IUPAC), 2008). The uncertainty generally includes many components which may be evaluated from experimental standard deviations based on repeated observations (Type A evaluation) or by standard deviations evaluated from assumed probability distributions based on experience or other information (Type B evaluation). The term uncertainty is preferred over measurement error because the latter can never be known (ISO, 2010). Uncertainty can also be seen as an estimate of the error in a measurement, often stated as a range of values that contain the true value within a certain confidence level (usually ± 1 for 68% confidence interval) (Deardorff, 2001).

Measurement uncertainty can also be termed error analysis. The following quotes indicates that 'It has been a considerable handicap to many experimenters that their formal scientific training has left them unequipped to deal with the common situation in which experimental error cannot be safely ignored.

Not only is awareness of the possible effects of experimental error essential in the analysis of data, but also its influence is a paramount consideration in planning the generation of data, that is, in the design of experiments. Therefore, to have a sound base on which to build practical techniques for the design and analysis of experiments, some elementary understanding of experimental error and of associated probability theory is essential' (Deardorff, 2001. p 3). From this one could deduce that the process of scientific inquiry naturally leads to the important questions about how well an empirical result is known, whether or not the result agrees with a hypothesis or theoretical prediction, and whether the result can be verified by other researchers. In order to answer these basic questions, the uncertainty of the measured result must be estimated and quantified to indicate the degree of confidence associated with the measurement. Only after the uncertainty of an experimental result is established can a reasonable conclusion be made or drawn about how the result compares with a theoretical prediction or some other experimental value is true or not.

Every measurement is subject to some uncertainty. A measurement result is only complete if it is accompanied by a statement of the uncertainty in the measurement. Measurement uncertainties can come from the measuring instrument, from the item being measured, from the environment, from the operator, and from other sources. Such uncertainties can be estimated using statistical analysis of a set of measurements, and using other kinds of information about the measurement process. There are established rules for how to calculate an overall estimate of uncertainty from these individual pieces of information. The use of good practice such as traceable calibration, careful calculation, good record keeping, and checking can reduce measurement uncertainties. When the uncertainty in a measurement is evaluated and stated, the fitness for purpose of the measurement can be properly judged (Bell, 1999). In addition the concept of Measurement uncertainty without results of accuracy and precision of measurement is no measurement at all.

Measurement Accuracy

Accuracy may be seen as 'telling the truth' about a physical quantity (Wang, 2006). Telling the truth of a physical quantity might mean giving the validity of that physical quantity or saying that such a physical quantity if free from mistake or error or the degree of conformity of a measure of that physical quantity to a standard or a true value is correct (Wordsworth, 1998). It could also be seen as the closeness of a measurement to the "true" value for a specific physical quantity and which can be expressed as either an absolute error or a relative error.

True value is a value that is consistent with the definition of a given particular quantity. A true value by nature is indeterminate; this is a value that would be obtained by a perfect measurement. The value that is approached by averaging an increasing number of measurements with no systematic errors (Deardorff, 2001).

Measurement Precision

Precision may be seen as the degree of consistency and agreement among independent measurements of a quantity under the same conditions. Better still it is a measure of how well the result has been determined (without reference to a theoretical or true value), the reproducibility or reliability of the result (Deardorff, 2001; Allie et al, 2005). Thus if precision is degree of consistency and agreement among independent measurement, then one cannot leave out the fineness of scale used in measuring such physical quantity. However, the fineness of scale of a measuring device generally affects the consistency of repeated measurements, and therefore, precision of measurement. The ISO has banned the term precision for describing scientific measuring instruments because of its many confusing everyday connotations (Deardorff, 2001), that is people interchange precision for accuracy and accuracy for precision. Therefore precision is the agreement established among several measurements that have been made in the same way or it is how well a measurement can be reproduced over a period of time.

Reporting Measurement Uncertainty

To report measurement of a physical quantity, some quantitative estimate of the quality of the measured result should be given so that people who use the result can assess its reliability. This is because without an indication of quantitative estimate of the quality of the measured result, measurement results cannot be compared, either among themselves or with theoretical or reference values and or experimental value (Deardorff, 2001). Also since there is always a margin of doubt about any measurement, one need to ask 'How big is the margin?' and 'How bad is the doubt?' Thus, two numbers are really needed in order to quantify an uncertainty. One is the width of the margin, or interval. The other is a confidence level, and states how sure one result of the 'true value' is within that margin (Bell, 1999). For example, one might say that the length of a certain stick measures 20 centimetres plus or minus 1 centimetre, at the 95 percent confidence level. This result could be written as 20 cm ±1 cm, at a level of confidence of 95%. The statement indicated that one is 95 percent sure that the stick is between 19 centimetres and 21 centimetres long. There are other ways to state confidence levels.

However, many scientists and engineers do not explicitly report the uncertainty of their measurements, so that the reader or a layman is forced to assume that the result is known to the precision implied by the number of significant figures. For example, v = 20.2 m/s implies an uncertainty of ± 0.1 m/s or ± 0.5%. However, there are many cases where data are improperly reported with excessive precision (i.e. extra digits) that is not justified by the experimental procedure, a practice that is careless, misleading, and could even be considered unethical. Even when the uncertainty in a measured value is explicitly reported (e.g., ± 0.1 m/s), the meaning is not always clear because there are various methods and formats for reporting uncertainties. The following table shows the most common formats:

As can be seen (Table 1) not only are there differences in notation with essentially the same meaning, but depending on the source and context, the quoted uncertainty could represent a 68%, 95% or evens a 99% confidence interval of a measured quantity (Deardorff, 2001).

In an effort to avoid this kind of confusion, the International Organization of Standardization (ISO) has recently specified universal guidelines for expressing the uncertainty of measurements (Deardorff, 2001). These guidelines are designed to provide a uniform method for comparing measurements made in different countries in the fields of science, engineering, industry, commerce, and regulation.

Effects of Measurement Uncertainty

The effects that give rise to uncertainty in measurement can be either random and or systematic.

1. Random – this occurs when repeating measurement gives a randomly different result. If so, then the more measurements one make, must go with calculation of average, the better an estimate one can expect to get.

2. Systematic – this occurs when the same influence affects the result for each of the repeated measurements. In this case, you learn nothing extra just by repeating measurements. Other methods are needed to estimate uncertainties due to systematic effects, e.g. different measurements, or calculations.

Error in Scientific Measurement

An Error may be referred to as the uncertainty in measurement. It is the difference between the measured value and the 'true value' of the thing being measured. (I.e. measure and which is never known exactly) and sometimes it is referred to as the "absolute error" to distinguish from "relative error". It is also the amount of deviation from a standard or specification (Bell, 1999). However the ISO clearly distinguish between the terms error and uncertainty (Deardorff, 2001; Allie et al, 2005)

Types of Error

Random Error: it is the result of a measurement minus the mean that would result from an infinite number of measurements of the same measure and carried out under repeatable conditions. It is also a statistical fluctuation (in either direction) in the measured data due to the precision limitations of the measurement device (Deardorff, 2001).

Causes of measurement Error

1. Instrument errors: Accuracy, range, response time, age of instrument, etc.
2. Calibration errors: Models, standards.
3. Operator error (human error).
4. Measurement location error.

Causes of Measurement Errors and Uncertainties

Many things can undermine a measurement. Flaws in the measurement may be visible or invisible. This is because real measurements are never made under perfect conditions. Errors and uncertainties can come from:

1. The measuring instrument - instruments can suffer from errors including bias, changes due to ageing, wear, or other kinds of drift, poor readability, noise (for electrical instruments) and many other problems.
2. The item being measured - which may not be stable. (Imagine trying to measure the size of an ice cube in a warm room.)
3. The measurement process - the measurement itself may be difficult to undertake. For example measuring the weight of small but lively animals presents particular difficulties in getting the subjects to co-operate.
4. 'Imported' uncertainties - calibration of your instrument has an uncertainty which is then built into the uncertainty of the measurements you make. (But remember that the uncertainty due to not calibrating would be much worse.)
5. Operator skill - some measurements depend on the skill and judgement of the operator. One person may be better than another at the delicate work of setting up a measurement, or at reading fine detail by eye. The use of an instrument such as a stopwatch depends on the reaction time of the operator. (But gross mistakes are a different matter and are not to be accounted for as uncertainties.). For example Visual alignment is an operator skill. A movement of the observer can make an object appear to move. 'Parallax errors' of this kind can occur when reading a scale with a pointer (Bell, 1999)
6. Sampling issues - the measurements one makes must be properly a representative of the process one is trying to assess. For example, if one is choosing samples from a production line for measurement, such a person must not always take the first ten made on a Monday morning.
7. The environment - temperature, air pressure, humidity and many other conditions can affect the measuring instrument or the item being measured.

Empirical Studies on Students' Understanding of Measurement Uncertainty

Lubben and Millar (1996) surveyed over 1000 United Kingdom students aged 11, 14, and 16 about the reason for repeating measurements, how to handle repeated measurements and anomalous readings, and the significance of the spread in a set of data. They identified a pattern of progression in the understanding of empirical data with age and experience (see Table 2). They also suggested that other research tools using interviews should be developed for further investigation into students' conceptions about measuring, accuracy and precision, random and systematic errors, sample size, and the evaluation of small differences between measurements to decide if the difference is significant or not.

The suggestions made by Lubben and Millar were pursued by a group of researchers from university of York, UK and University of Cape Town, South Africa. These researchers in 1998 conducted a study to examine 121 first-semester physics students and their ideas about the reliability of experimental data (Allie & Buffler, 1998). This study at the University of Cape Town, South Africa, used written questions and interviews with students to confirm many of the findings of Lubben and Millar and extend their model of ideas concerning experimental data (Level I in Table 1). Even though the students in this study were older than those in the secondary school study, the model proposed by Lubben and Millar was still useful for classifying the procedural ideas of these university students who mostly fell into levels F, G, and H (Table 2). The study used nine written "probes" or scenarios all related to the same experimental situation where a ball is released from rest, rolls down a ramp, and lands on the floor some distance *d* from the edge of the table on which the ramp is secured.

Three of the probes dealt with the reasons for repeating measurements and the other three dealt with sets of experimental data (how to handle an anomalous measurement, how to compare two sets of measurements having the same mean but different spreads, and how to compare two sets of measurements having similar spread but different means). The findings are as follows 58% of the students reasoned that measurements of the distance and time the ball fell needed to be repeated in order to establish an accurate mean value. The remaining students i.e. 42% were classified into nearly even clusters of thinking. One cluster (7%) did not see a purpose in repeating distance measurements, but all of these "non-repeaters" reasoned that several time measurements need to be taken. Another small cluster (8%) of "repeaters" believed that additional time and distance measurements are needed to practice and perfect the experimental process of taking measurements. The final cluster (10%) of "confirmers" suggested repeating distance measurements in order to find a recurring value. Responses to the probes (i.e. written questions) that dealt with sets of experimental data showed that students were not able to differentiate clearly between the overall spread of the data set and the differences between the individual data points within the set.

In 2001, the procedural understandings of first year university students before and after instruction were investigated in the context of experimental work in physics by (Allie et al, 2001). A written instrument was used to probe the students' ideas about data collection, data processing and data comparison. The responses of the students were analyzed in terms of “point” and “set” paradigms which were proposed as a framework for evaluating the effectiveness of laboratory curricula in South Africa.

Since most of the South African First year Physics students had little or no first hand practical experience, a prime aim of the laboratory course was to develop the notion of measurement. Aspects of data collection and data processing were addressed by exercises such as drawing up tables, taking several measurements of a quantity, plotting graphs, fitting straight lines, and calculating the mean and the standard deviation from the statistical formulae as well as graphically from a Gaussian curve. The idea of spread in data was introduced by getting the class to measure the time of travel of a sound pulse over a given distance. The readings were processed to form a distribution (a Gaussian curve results) from which the key ideas of mean and uncertainty were introduced.

Findings showed that the pre- and post-tests with regard to students’ understanding about repeating measurements during data collection, that before instruction, majority of students (76%) subscribed to the point paradigm concept while after instruction there appeared to be a large shift (16% to 71%) towards the set paradigm concept. However, it was not clear as to whether these students have embraced the set paradigm concept as a whole. For example, many students indicated that the purpose of repeating measurements was to allow for a mean to be generated (rather than a mean being a way of dealing with the inherent scatter in the data). This suggests there was a strong possibility that elements of the set paradigm concept are being used by rote or on an ad hoc basis. The degree to which this was the case requires the combined analysis of the other probes.

The pre- and post test findings for the 3 probes that dealt with the comparison between two data-sets i.e. , the first of the three probes required students to compare two sets of data with the same mean but different scatter, while the second probe provided two sets of data with different means but the same (overlapping) spread. The third probe presented two data-sets with different means and different but overlapping spreads. Thus, students were grouped according to whether or not their responses across the three probes were consistent with the set paradigm concept. As expected from the background of the students, none were classified as using the set paradigm concept consistently prior to instruction. After instruction only 26% responded consistently in terms of the set paradigm concept while more than two thirds (70%) resorted to both paradigms, possibly indicating either rote or ad hoc application of the elements associated with the point paradigm concept.

Allie et al in 2001 carried out a research on the point and set paradigm concepts: towards effective teaching and learning in the first year physics laboratory. Student responses to written probes were administered at the beginning of the year results compared to those written after a 12-week laboratory course. The “point” and “set” paradigms were used to analyze the responses to the probes. Their finings were that More than 84% of the students could be classified as subscribing to the point paradigm concept prior to instruction. Even when an action associated with the set paradigm concept, for example finding a mean, was used by the students, their responses to the probes which dealt with the spread in sets of data confirmed that their set reasoning was either undeveloped or nonexistent.

After their laboratory course, 87% of the students were able to represent a set of measurements of a quantity by a mean. However, the fact that the mean of a set of measurements has little significance without some indication of an interval of uncertainty seems not to have been widely internalised. This fact was evidenced by the response patterns in the probes which required students to use the set paradigm concept at a deeper level. Although 93% of the students recognised the presence of the scatter in the data after instruction, when asked to use the spread to make a decision, only 23% of the students were able to communicate appropriate reasoning associated with the set paradigm concept. On the other hand, 57% of the students correctly opted to reason on the basis of overlapping intervals when confronted with data already represented by a mean and a standard deviation. This suggests that the present form of their laboratory course, although fairly successful in its aims of teaching students the formalism of data analysis, was not able to provide the necessary links between the inherent statistical nature of measurement, and the formal techniques for data processing and analysis.

The results from the present study suggest that the broad purpose of laboratory instruction should be directed towards changing a shift in the paradigm used by the student. Ideally this would involve parallel development both of the use of the operational tools of data reduction and statistical analysis, and an understanding of the nature of data and measurement. However, most laboratory curricula emphasise the development of laboratory procedures with little attention being paid to commensurate understanding of the deeper reasons for these procedures. Such laboratory courses, including theirs, tend to emphasise the formalistic rules of the statistical processing of data and omit to include aspects that address the conceptual framework. Therefore laboratory curricula need to be designed in which the concepts underlying the experimental procedures for data collection and analysis are explicitly addressed.

Teaching activities are required which allow students to appreciate the collective nature of a series of measurements and that the mean and the width represent the set of measurements as a whole. A student’s intuition regarding the spread in data needs to be explicitly linked to the formal mathematical procedures for analyzing the spread in data set. A similar conclusion has also been reached by Evangelinos, Psillos & Valassiades, (1998) who recommended that ‘probabilistic reasoning in the context of lab work should be presented not only as a technique for data treatment but as an inherent feature of scientific enquiry’. In particular, they attempted to devise a teaching sequence that utilised the students’ everyday notion of ‘approximate’ in bridging the gap between ‘exact’ (point paradigm concept) and ‘probabilistic’ (set paradigm concept) types of reasoning.

Methodology

Research Design

The design of this study was a mixed method research design. It is a combination of qualitative and quantitative techniques (Ary, Jacobs & Razavieh, 2002; Ray, 2003). The quantitative technique was used to test the research question of the study on SHS3 physics students’ understanding of measurement uncertainty, of length and time.

Cross-sectional survey (Ary et al, 2002; Ray, 2003) was used in this study with SHS3 physics students. The SHS3 physics students were randomly selected from category A, category B, category C, and category D (Ghana Education Service, 2009) schools in Volta region. The close and opened ended questionnaire items was adapted from Allie et al, (2003) and used to gather data from SHS3 physics students on their understanding of measurement uncertainty of length and time.

All the intact class of SHS3 physics students in each of the categories of schools were involved in the study. The close and opened ended questionnaire items were based on SHS3 physics students understanding of measurement uncertainty of length and time The use of the adapted close and opened ended questionnaire items (Allie et al, 2003) from Department of Physics of the University of Cape Town, South Africa and University of York, UK was appropriate in this study because it helped the researcher in this study.

In addition to the close and opened ended questionnaire items of the cross sectional survey design, structured interview of the SHS3 physics students was also conducted to elicit further information from physics students which might not have appeared on the questionnaire items and to also validate the written responses of the students on the questionnaire items.

Population

The population of the study was 642 SHS3 science students in Volta region. These SHS3 science students were selected from eleven (11) SHS and one (1) SHTS in Volta region (Ghana Education Service, 2009). The twelve SHS and SHTS were categories into category A, category B, category C and category D (Ghana Education Service, 2009).

Sample and Sampling Procedure

The sample for the study was 422 SHS3 and SHTS3 science students. This sample size of science students were simple randomly selected from the population. Within this 422 science students, 20 students were again sampled purposively and interviewed. The 20 students were purposively selected based on how they responded to the questionnaire items of the study. The 422 sample size of SHS3 and SHTS3 science students formed 65.73% of the 642 of SHS3 and SHTS3 of science students in the eleven SHS and one SHTS in the region. The 65.73% sample of the population in this study was more than 10% sample of the population as indicated in (Ary et al, 2002; Ray, 2003); they argued that for a descriptive research, it is convenient to select 10 to 20 percent of the population. A sample of 65.73% of the population was therefore appreciably adequate for this study.

Simple random sampling method was used to select the sample for the study. This was done in order to get an appreciable representation of students in each category of schools i.e. category A, category B, category C and category D (Ghana Education Service, 2009). A total of four hundred and twenty two (422) SHS3 and SHTS3 physics students were sampled for the study. These total numbers of four hundred and twenty two (422) SHS3 and SHTS3 physics students were made up as follows;

1. The first SHS was a category A school. It had Forty nine (49) students present in class at the time of administration of the test.
2. The second SHS was a category A school. It had Forty nine (49) students present in class at the time of administration of the test.
3. The third SHS was a category B school. It had forty six (46) students present in class at the time of administration of the test.
4. The four SHS was also a category B school. It had thirty seven (37) students present in class at the time of administration of the test.
5. The five SHS was also a category B school. It had thirty nine (39) students present in class at the time of administration of the test.
6. The sixth SHS was a category C school. It had thirty eight (38) students present in class at the time of administration of the test.
7. The seventh SHS was a category D school. It had forty (40) students present in class at the time of administration of the test.
8. The eighth SHS was also a category C school. It had twenty three (23) students present in class at the time of administration of the test.
9. The ninth SHS was also a category A school. It had thirty six (39) students present in class at the time of administration of the test.
10. The tenth SHS was also a category D school. It had thirty eight (38) students present in class at the time of administration of the test.
11. The eleventh SHS was also a category D school. It had thirty seven (37) students present in class at the time of administration of the test.
12. The twelfth SHS was also a category C school. It had twenty six (23) students present in class at the time of administration of the test.

Eleven SHS and one SHTS offering physics in the various categories of schools by the Ghana Education standard were randomly selected from the thirty 32 SHS and SHTS (Ghana Education Service, 2009). All the twelve SHS and SHTS were selected from the categories based on classification of Ghana Education Service, which is Category A, Category B, Category C and Category D (Ghana Education Service, 2009). The selections of the eleven SHS and one SHTS were done by using Microsoft Excel software. A list of names of category A, category B, category C, and category D were obtained (Ghana Education Service, 2009). These names of schools in their categories were imputed into Microsoft Excel software. All the schools in the categories were highlighted, and then sort ascending in the tool bar of Microsoft Excel software clicked. This was done to arrange the schools in each category in alphabetical order. Rand also in the tool bar of the auto sum of Microsoft Excel software was clicked to assign random numbers to each of the schools in each category. Since this study looks at physics students understanding of measurement of length and time, but not physics students' performance in senior high schools, the use of the classification of Ghana Education Service is appropriate for this study. The reason being that the classification (Ghana Education Service, 2009) was based on the availability of facilities (i.e. boarding or day, and classrooms among other facilities) in the senior high schools of Ghana, but not on performance of students and students' entry behaviours.

With this 65.73%, three SHS or SHTS were selected from the category A schools, three SHS or SHTS from the category B schools, three SHS or SHTS from the category C schools and three SHS or SHTS from the category D schools. The reason for these 65.73% selection of physics students from each category of schools was based on the assumption that the sample size of a population should not be less than 10% (Ary et al, 2002; Ray, 2003). Thus selecting 65.73% sample size from each category would give a fare representation of SHS3 or SHTS3 of physics students to be included in the study. Each selected school was identified by a confidential code alphabet. Also each student in the selected school was identified by their names there after and throughout the study. Students' names were used in the study in order to identify them for interviewing. Table 3, shows the coding of both senior high schools with the size of the participated SHS3 and SHTS3 physics students in each of the school.

Instruments

The research instrument (close and opened ended questionnaire) was adapted from (Allie et al, 2003) for the study. This was accompanied with a structured interview for respondents to give opinions on each item in the close and opened ended questionnaire items. The close and opened ended questionnaire items was adapted (Allie et al, 2003) for this study because it was the most appropriate instrument in view of the purpose of the study considering the financial and time constraint of the study.

The close and opened ended questionnaire items were of one dimension i.e. SHS3 physics students understanding of measurement uncertainty of length and time. It was comprised of two close ended or multiple-choice items and its corresponding two easy or opened ended items (No Uncertainty-1 and No Uncertainty-2). The corresponding easy or opened ended items of the close ended or multiple-choice items was for the SHS3 physics students to illuminate their reasoning of each of the option selected in the close ended or multiple-choice items. Each of the items in the questionnaire under the dimension was targeted at a particular aspect of measurement and seeks to determine students' decision and at the same time illuminated students reasoning.

The dimension has been put into two questionnaire items. All the items under the dimension in the questionnaire had the same form. A brief stem of text posited a situation where decisions had to be made concerning the experimental procedure (Appendix A). A number of options were presented in each item of the questionnaire by cartoon characters, purposely included to avoid gender and race bias in influencing the respondent's choices. The questionnaire items called for an explanation of each choice made by the physics students in each item.

The questionnaire item was in two parts i.e. part one and two. Part one consisted of four items. These four items elicited information on physics students' background, which were students surname, students' first name, location and type of school. This student's background was used to help identify each student for interviewing. Part two consisted of the dimension, which were students understanding of measurement uncertainty, (Appendix A).

The close and opened ended questionnaire item was of duration of sixty five minutes. Five minutes was allowed for the students to read through the given questionnaire items and for any further questions and further clarification before the commencement of the questionnaire items. Sixty minutes for the actual answering of the given close and opened ended questionnaire items by the students. The sixty minute time was allowed in order that the students would have ample time to respond to the close and opened ended questionnaire items, since the questionnaire items was not a speed test but rather an understanding of measurement of distance and time, thus the questionnaire items requires much time for the students to respond since it involves much reasoning and thinking by the students.

The Interview Guide

A variety of interview methods exist (Ary et al, 2002; Ray, 2003), they are standardized (structured), semi-standardized (semi-structured), and un-standardized (unstructured). The decision to use the structured interview as a follow up data gathering method to the questionnaire item was influenced by (Ary et al, 2002; Ray, 2003). They maintained that structured interview allows respondents to freely speak for themselves in order to provide their perspective in words and other actions, and that it usually involves personal visit to respondents at home, at school and at work.

In this study, the interview guide schedule was made up of two items (i.e. NU1, and NU2,) see Appendix B. The two interview schedule items were comprised of five questions each. Two questions went for students who had the questionnaire items wrong, and three questions went for students who had the questionnaire items right. Even though structured interview usually involves much cost on the part of the researcher such as it took a great deal in meeting the students, interviewer bias which is due to the interviewer own feelings, attitudes, gender, race age and among others which might influence the way and manner the questions were asked, and social desirability which occurs when respondents want to please the interviewer by giving acceptable responses that might not have necessarily be given on the questionnaire items and also time consuming when it comes to the transcribing of the interview responses (Ary et al, 2002; Ray, 2003). However, its use in this study allowed the researcher enough flexibility in re-wording questions that would fit into the interview, it was more conversational, and it made the interviewee saw, and felt the need to be interviewed on items in the questionnaire (Ary et al, 2002; Ray, 2003). Also it enabled the researcher find the target sample to be interviewed and most importantly it served as a back up instrument to the close and opened ended questionnaire items. This back up instrument enabled the researcher to cross examine the physics students who had earlier responded to the close and opened ended questionnaire items (Ary et al, 2002; Ray, 2003). The cross examination enable the researcher to verify whether the students responses to items in the close and opened ended questionnaire were really what they meant or other wise or whether the written responses of the physics students were interpreted in line with the ideas the physics students wanted to communicate (Ary et al, 2002; Ray, 2003).

The responses from the students involved in the interview were hand written by the researcher. Audio taping might have been better but because audio taping of responses from respondents may possibly make the students nervous, less apt to listen and less apt to respond freely because students responses would be recorded (Ary et al, 2002; Ray, 2003) it was better for the researcher to write their responses down with the use of pen and paper. The structured questions were focused on SHS3 physics students understanding of data collection of length and time in category A, category B, category C, category D schools in Volta region.

Validity and Reliability of the Instrument

The instrument of the study had already been validated with 230 South African freshmen undergraduate students (Allie et al, 2003). Allie et al, (2003) developed a range of items on a questionnaire for use in their investigation. Each of the items in the questionnaire was targeted at a particular aspect of measurement and sought to determine students' decision and at the same time illuminated students reasoning. This questionnaire was validated by giving it to other research members to independently look at. This was done in order to identify different categories of reasoning. They further went ahead to interview thirty (30) volunteered students for about thirty (30) minutes. The interview allowed (Allie et al, 2003) to further validate the close and opened ended questionnaire items by checking on students understanding of the questionnaire items and the interviewers' interpretation of their responses.

However, since the same instrument was used in this study with Ghanaian SHS3 physics students, face and content validity were again assessed by given the questionnaire item to three SHS physics teachers from the pre testing school (University Practice Senior High School) in Cape Coast, and two colleagues who majored in physics. They were given the close and opened ended questionnaire items and were asked to assess the quality of each item of the questionnaire. This was done in the context of ambiguity of item, clarity of item and generality of item. The three physics teachers and the two colleagues of physics worked independently on evaluation of the close and opened ended questionnaire items. They independently approved on the questionnaire items adapted from Allie et al, (2003). This meant that all the items of the questionnaire were clear, not ambiguous and every SHS3 physics students in Ghana can respond to it.

The validity of the instrument was improved by conducting a pretest using an intact class of SHS3 physics student of in University Practice Senior High school (UPSS) in the Cape Coast municipality. The questionnaire item was distributed personally by the researcher to the SH3 physics students in their science classroom. The SHS3 physics students responded to the questionnaire items in the presence of the researcher. The questionnaire items were collected after completion, personally by the researcher and then analyzed. The intact class was made up of forty six (44) SHS3 physics students. The mean of the intact class was 32.00; the standard deviation was 24.83; and variance 616.56. The pre-tested school was randomly selected from six (6) schools. The pretest was done so that the ambiguous items in the questionnaire could be removed or reworded so that they would have the same meaning for the respondents. The validity of the instrument was further enhanced by conducting personal interview with twenty SHS3 physics students purposively selected by the researcher. The twenty physics students were purposively selected because of the way they responded to the questionnaire items. The twenty physics students that were involved in the interview were spread into the four categories of schools i.e. category A, category B, category C and category D. This means that five physics students were interview from each of the categories of schools.

Data Collection Procedure

Before the research data were collected from SHS3 physics students, an introduction letter was first taken from the head, Department of Science and Mathematics Education of University of Cape Coast and sent to the selected categories of schools. Initial visits were made to the selected categories of schools in order to meet the heads, deliver the research visit introductory letter from the Department of Science Education and to familiarize with the SHS3 physics students and the subject tutors. The meeting of the heads of schools, teachers and students enabled the researcher an opportunity to explain the objectives of the study and to seek their consent to conduct the research in their schools. It also helped the researcher the opportunity to agree on the day(s) and time for the administration of the research instruments. It also gave the schools and SHS physics students the opportunity to decide on when to respond to the closed and opened ended questionnaire items; whether to respond to the questionnaire items before the normal hours, during the school hours or after the school hours.

On the actual day for the data collection in the schools, the researcher re-explained the rationale of the study to the SHS physics students and assured them of confidentiality of their responses. The researcher with the help of the subject tutors administered the closed and opened ended questionnaire to the SHS3 physics students on the same day. An intact class of SHS3 physics students was used throughout in each of the selected schools. Each of the closed and opened ended questionnaire lasted for sixty minutes. The instrument did not require the use of gender (Allie et al, 2003). It took the researcher duration of two weeks to move round the twelve (12) selected schools to collect data.

Data Analysis

Research question i.e. what is SHS-3 Physics understanding of measurement uncertainty of length and time in category A, category B, category C, category D schools in Volta region? Was analyzed using frequency distribution by the use of SPSS 16.0.

The criteria that was employed to determine students understanding of measurement uncertainty of length and time was 50% using frequency distribution by the use of SPSS 16.0. Thus below 50% students understanding was with the point paradigm concept and above 50% students understanding was with the set paradigm concept. Correct option went for ‘set paradigm concept’; wrong option went for point ‘paradigm concept’, unclear students written response went for ‘Not Classified’ and a mixer of correct option but wrong written response and vice versa went for ‘mixed paradigm state’ and any other written response which is not either right or wrong went for ‘confusion / own paradigm state . Determination of range of values with calculation of mean went for internalized set paradigm concept. Determination of range of values without the calculation of mean went for consistent set paradigm concept.

Results and discussion

Students’ Understanding of Measurement Uncertainty

The research question sought to find out whether physics students understood measurement uncertainty of length and time. Students’ understanding of measurement uncertainty was tested on two items i.e. measurement uncertainty-1 (NU1) and measurement uncertainty-2 (NU2).

Measurement Uncertainty-1 (NU1)

The NU1 item sought to find out from the students whether enough practice could help them perfect their measurement technique so that only one measurement can give the true value. The expected response required from students is option (B); No, that is not possible. The reason is that enough practice of an experiment could still bring about errors such as human errors, instrument errors and experimental condition could change within a second. Due to these errors no true value can be gotten in an experiment but rather an approximate / equivalent value by the calculation of the mean and standard deviation of the mean.

The percentage number of students that selected option (C) was 42.3%. This selected option (Table 4) is in line with the set paradigm concept; hence the students seemed not to understand measurement uncertainty-1.

Students’ written responses were coded ‘Not Classified’ meaning students’ responses were not clear to the researcher; and ‘No Explanation’ meaning students were not able to give any response or explanation to their selected options.

Students were expected to respond to the option (B) selected on measurement uncertainty-1. The responses of the students to option (B) would show whether their reasoning is in line with the reasoning of the set paradigm concept on measurement uncertainty-1. Thus by the set paradigm concept, there is no experimental measurement on this earth that can give a one time measurement.

The responses from students on measurement uncertainty 1 were expected to be it is impossible to have one measurement giving a true value, since all measurements are prone to uncertainties. With this response, the students could be said to have internalise the set paradigm concept. The percentage of students that could be said to have internalised the set paradigm concept was 20.1%. However, 28.6% of the students (Table 5) were consistently with the set paradigm concept, and 38.2% of students were not able to explain the option they selected. Also 6.6% of students were observed to be confused (i.e. not classified). The findings of this study on measurement uncertainty-1 does agree with Allie et al, (2003) in the sense that most of the students in their study as at the time were classified as subscribing to the point paradigm concept prior to instruction.

Table 1: Common formats for reporting Uncertainties

Example	Explanation	Reference
m = 2.32 g with a combined standard uncertainty u_c = 0.05 g	u_c is the combination of all Type A (statistical) and Type B (Systematic/other) errors; denotes approx. a 68% confidence level.	ISO Guide to the Expression of Uncertainty in Measurement, 1993.
m = (2.32 ± 0.05) g	The uncertainty generally represents ± 1s or the 68% confidence level for the measurement.	P. Bevington & K. Robinson. Data Reduction and Error Analysis for the Physical Sciences, 1992, p. 39.
m = 2.32 g ± 2% or m = 2.32 (2%) g	2% is a relative uncertainty, but the confidence level is not clear	
Example	Explanation	Reference
m = 2.32 SE 0.01 g	SE = standard error	C. David. J. Chem. Educ. 1996, 73, p. 46.
55% favor candidate A (± 3% margin of error)	the margin of error in a poll generally represents a 95% confidence interval	J. Taylor. Error Analysis, 1997 p. 14.
m = 2.32 g with an expanded uncertainty U = 0.10 g	Calibration certificates usually report a 95% confidence level with coverage factor k = 2.	NIST Calibration Services Users Guide 1998, p. 4.
m = 2.324(52) g	Numbers in parentheses indicate experimental uncertainties in last two digits" This notation is common in atomic and nuclear physics.	Table of fundamental Constants found in several popular physics textbooks. E. R. Cohen, B. N. Taylor, Rev. Mod. Phys. 1987, 59:1121.
accuracy = ± (1% of reading + 2 digits)	Manufacturers typically specify instrument tolerance limits, which generally represent a 99% confidence level, but may be 95% or some other confidence level depending on marketing strategy.	Fluke. Calibration: Philosophy and Practice, 1994, p. 20-7, 22-4. Phone conversation with Fluke application engineer, Mar.1999.

(Refer Deardorff, 2001. p 19-20)

Table 2. Model of Progression of Ideas concerning Experimental Data

Level	Student's view of the measuring process (ordered novice to expert)
A	Measure once and this is the right value.
B	Unless you get a value different from what you expect, a measurement is correct.
C	Make a few trial measurements for practice, and then take the measurement you want.
D	Repeat measurements till you get a recurring value. This is the correct measurement.
F	Take a mean of several measurements to take care of variation due to imprecise measuring. Quality of the result can be judged only by authority source.
G	Take a mean of several measurements. The spread of all the measurements indicates the quality of the result.
H	The consistency of the set of measurements can be judged by the spread of the data, and anomalous measurements need to be rejected before taking a mean.
I	The consistency of data sets can be judged by comparing the relative positions of their means in conjunction with their spreads.

Note: Levels A-H was proposed by Lubben and Millar, while category I was proposed by Allie et al. (Refer Deardorff, 2001, p 26)

Table 3: Alphabet Codes of Senior High Schools and Number of participated SHS3 Physics Students

Category A

School code	Students codes	Number of participated SHS3 physics students
A_1	$A_{1\,(1)}$-$A_{1\,(50)}$	49
A_2	$A_{2\,(1)}$-$A_{2\,(50)}$	49
Total		98

Category B

School code	Students codes	Number of participated SHS3 physics students
B_1	$B_{1\,(1)}$-$B_{1\,(50)}$	46
B_2	$B_{2\,(1)}$-$B_{2\,(50)}$	37
B_3	$B_{3\,(1)}$-$B_{3\,(50)}$	39
Total		122

Category C

School code	Students codes	Number of participated SHS3 physics students
C_1	$C_{1\,(1)}$-$C_{1\,(50)}$	38
C_2	$C_{2\,(1)}$-$C_{2\,(50)}$	23
C_3	$C_{3\,(1)}$-$C_{3\,(50)}$	26
Total		87

Category D

School code	Students codes	Number of participated SHS3 physics students
D_1	$D_{1\,(1)}$-$D_{1\,(50)}$	40
D_2	$D_{2\,(1)}$-$D_{2\,(50)}$	38
D_3	$D_{3\,(1)}$-$D_{3\,(50)}$	37
Total		115

Table 4: Students' selected option on NU1 (N = 422)

Items	Paradigm Type	Frequency	Percentage
Measurement Uncertainty-1	Point Paradigm concept	243	57.7%
	Set Paradigm concept	179	42.3%

Table 5: Students' written response on Uncertainty-1 (NU1) item (N = 224)

NU1 (B) written response	Frequency	Percent
No Explanation	87	38.2
Not Classified	24	6.6
Because one measurement cannot give the true value, but several measurements with their average gives the true value	45	20.1
Because the speed the ball used to reach d differs from one experiment to the other	2	.5
Because average cannot be determined by only one measurement. Also if the graph method is to be used one measurement cannot plot the graph and the slope cannot also be determined	2	.5
Because average cannot be determined by only one measurement. Also if the graph method is to be used one measurement cannot plot the graph and the slope cannot also be determined	2	.5
Because practicing/experimenting enough/ severally can only give very close values but cannot give a perfect value most especially with one measurement	64	28.6

Table 6: Students' selected option on NU2 Item (N = 422)

Items	Paradigm Type	Frequency	Percentage
Measurement Uncertainty-2 (NU2)	Point Paradigm concept	228	54.10%
	Set Paradigm concept	194	45.90%

Table 7: Students' written response on Uncertainty-2 (NU2) item (N = 224)

NU2 (B) written response	Frequency	Percent
No Explanation	107	48.7
Not classified	51	22.8
Because everything under this sun is physics and for that matter scientist can design such an experiment	1	.3
Because final experimental results cannot be predicted	2	.9
Because when you experiment, you get to know the accurate / exact or nearer values.	4	1.8
Because experiment in physics can only be done in the laboratory but not by discussion	1	.4
Because physics deals with things that happens as they have proves for everything	3	1.3
Because experiment can be performed under so many conditions which would affect the final results	2	.9
Because if such an experiment is done students will develop negative attitudes towards learning such as laziness and lower thinking abilities	1	.4
Because scientists always work with facts	1	.4
Because students need to experiment on their own in order to understand scientific measurement	1	.4
Because all experiment must be proved so that any other person can practice it and understand it	1	.4
Because of errors and uncertainties associated with every measurement both in the experimental results and experimental setup.	42	18.8

Measurement Uncertainty-2 (NU2)

The NU2 item sought to find out from the students whether it is possible for scientist to design an experiment that will provide a result with no uncertainty. The expected response required from students is option (B); it is not possible for scientist to design a physics experiment that will provide a result with no uncertainty. The reason is that man in it self is not hundred percent perfect and also because of wears and tears of equipments and experimental conditions that could vary from place to place, it is impossible for scientist to design such an experiment.

The percentage of students that selected option (C) was 45.9%. This selected option (Table 6) is in line with the set paradigm concept; hence the students seemed to understand measurement uncertainty 2 (Table 25).

Students' written responses were coded 'Not Classified' meaning students' responses were not clear to the researcher; and 'No Explanation' meaning students were not able to give any response or explanation to their selected options.

Students were expected to respond to the option (B) selected on measurement uncertainty 2. The responses of the students to option (B) would show whether their reasoning is in line with the reasoning of the set paradigm concept on uncertainty-2. Thus by the set paradigm concept, it is impossible for any scientist to design a physics experiment that will provide a result with no uncertainty, since all experiments are prone to errors.

The responses from students on measurement uncertainty 2 were expected to be, it is impossible to have such an experiment, since all experiments are prone to uncertainties. With this response, the students could be said to have internalise the set paradigm concept. The percentage number of students that could be said to have internalised the set paradigm concept was 18.8%. However, 48.7% of the students (Table 7) were not able to explain the option they selected. Also 28.8% of students were observed to be confused (i.e. not classified). The findings of this study on measurement uncertainty-2 does agree with Allie et al, (2003) in the sense that most of the students in their study as at the time were classified as subscribing to the point paradigm concept prior to instruction.

Five physics students were interviewed on measurement uncertainty items i.e. uncertainty-1 (NU1), and uncertainty-2 (NU2). These five physics students were conveniently selected based on the way they responded to the items. The interview was conducted in order to validate the written responses of the students on measurement uncertainty.

The following interview questions went to the physics students who had the item correct.

Researcher: "You chose option B under NU1; why was this option the correct answer?"

Student 1: "Scientifically one value experiment is not the best since errors which may be due to friction and other factors may affect the value. Several experiments of the same setup must be performed in order to get similar or consistent values".

Student 2: "Man and instrument naturally are not perfect. This is due to the fact that no matter how one is perfect with an experiment, external forces will still affect the results. Yet enough practice and perfecting one's techniques just like the slogan hard training easy battle, the measurements will be a little precise but not totally precise".

Student 3: "Experimenting enough gives very close values but not perfect Values".

The three students' responses were completely in line with the set paradigm concept. Hence these students have internalized the set paradigm concept.

Researcher: "Why did you not choose option B under NU1 item?"

Student 1: "This is because the speed of the ball used to reach d differs from one experiment to the other".

Student 2: "I chose option A because my watch gives me exact time, so with enough practice, physicists will be able to get one measurement that will give the true value".

The two students were confused, this is because comparing student 1 response to the preamble of NU1 item on the questionnaire, did not indicate that different speed of the ball were used. Also with student 2, there is no watch that can give exact time. This is because of the different altitudes that we have such as longitude and latitudes. However, comparing these students' oral responses to the selected options, they could be said to be in their own paradigm / conception.

The following interview questions went to the physics students who had the item correct.

Researcher: "You chose option B under NU2; why was this option the correct answer?"

Student 1: "The fact is that, Chemistry tells us that our atmosphere is full of impurities such as pressure, temperature and wind. Due to this an experiment must be performed several times to get consistent values".

Student 2: "Scientist cannot design an experiment without an error, since machine is not 100% efficient due to tears and wears of machine parts as a result of friction and sometimes mishandling of machine parts and rusting".

Student 3: "It would be impossible to perform an experiment and provide a result with no uncertainty since definitely there would be errors. It is even known that chemical reactions involves lost of mass which cannot be detected by most sensitive instruments; also it is not every food we take in our body system that is used for digestion. Thus experimental factors are inevitable, so one can only conclude by saying a more accurate result but not an accurate result".

The responses of the last two students have shown that they have internalized the set paradigm concept on measurement uncertainty 2, while that of student 1 is consistently with the set paradigm concept.

Researcher: "Why did you not choose option B under NU2 item?"

Student 1: "Because physics deals with things that happens as they have proves for everything"

Student 2: "This is to put scientist on guide so that they will be able to make sure every design they bring out after any experiment will be certain".

The two students' responses showed that they were confused. For example student 1 was of the view that physics has proves for everything. This view of this student is a fallacy because physics doe not have prove for everything in this world. And for student 2, there is no scientist that can design an experiment with certainty. However, comparing these students' oral responses to the selected options, they could be said to be in their own paradigm / conception. .

Key finding

With students understanding on data collection, two out of three items on data collection of students (i.e. RT and RD) were in line with the set paradigm concept of measurement, while one item on data collection (i.e. RDA) was in line with the point paradigm concept of measurement.

Conclusion

It has been reported that science students made deductions after obtaining only one reading from their experiments (WAEC 2000, 2002 and 2006). However, the findings of this study showed that science students understand how to; repeat time and repeat distance but they do not understand how to repeat distance again. In view of the fact that students face difficulty in understanding repeating of distance again, science teachers should lay much emphasis on this aspect.

Recommendation

Based on the findings of this study it is recommended that physics teachers should make effort to make scientific measurement by the set paradigm concept relevant to all senior high school science students in Volta Region of Ghana.

Suggestions for Future Research

It is suggested that this research can be carried out in other subject areas such as Chemistry, Mathematics and Biology in a wider perspective.

It is also suggested that this study should be given a nationwide dimension; this will enable policy makers to observe the true picture of science students towards their understanding of scientific measurement in order to obtain and employ professional physics science teachers at the Senior High Schools.

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Appendix A

Instrument-1 of the study

A 2 Item Questionnaire on Students' Understanding of Measurement Uncertainty

Senior High Schools Physics Students' Understanding of Measurement Uncertainty

SHS Students' form

Part 1: Background Questionnaire

Surname: …………………………………………………

First name: …………………………………………………….

School …………………………………………………….

Location of School / District: ....……………………

Type of School [SHS] [SHTS] [BUSINESS] [VOCATIONAL]

Part 2: Laboratory Procedures Questionnaire

Instructions

Write your name in the box above.
Inside this envelope there are pages numbered up to page 17.
Read the text below and answer the questions on each sheet.
If you need more space for your answers, then use the backs of the sheets.
It should take you about 5 minutes to answer each question.

Answer the questions in order and do not skip any sheet.
When you have completed a question, put the sheet inside this envelope and do not take it out again, even if you want to change your answer.

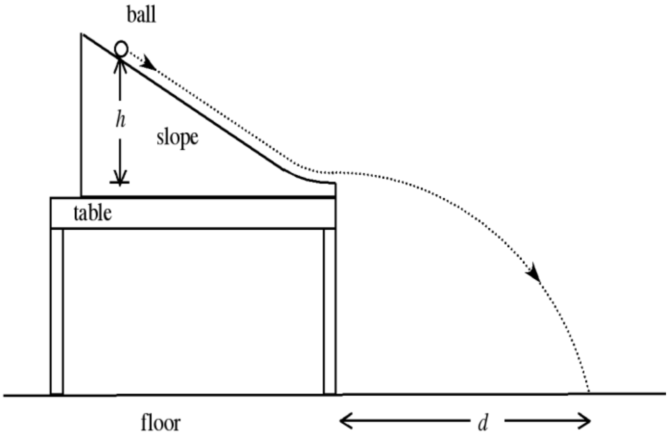
Note: It is possible that some answers may be similar or exactly the same as others. Please write all answers out in full, even if you feel that you are repeating yourself.

Experimental Context

An experiment is being performed by students in the Physics Laboratory.

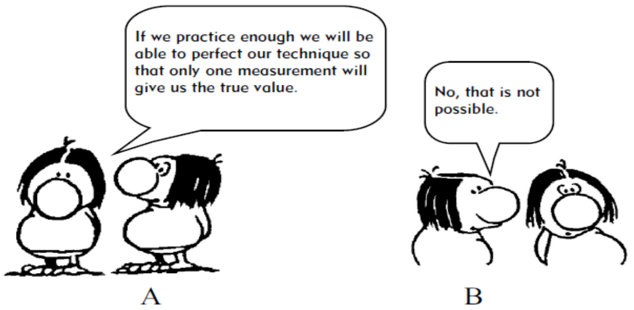
A wooden slope is clamped near the edge of a table. A ball is released from a height h above the table as shown in the diagram. The ball leaves the slope horizontally and lands on the floor a distance d from the edge of the table. Special paper is placed on the floor on which the ball makes a small mark when it lands.

The students have been asked to investigate how the distance d on the floor changes when the height h is varied. A meter stick is used to measure d and h.



NU1

When they are finished, the two groups discuss how they can improve their rolling ball experiment next time.



With which group do you most closely agree? (Circle ONE): A B

Explain your choice.

…………………………………………………………………
…………………………………………………………………
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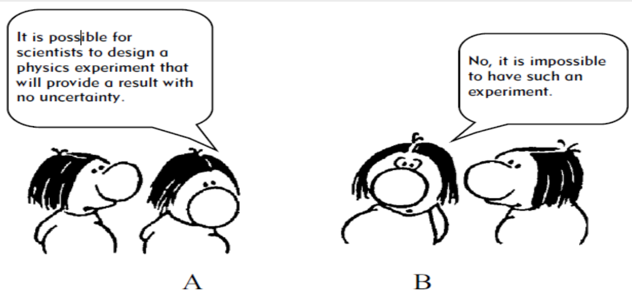
NU2

The two groups continue to discuss doing experiments in physics...



With which group do you most closely agree? (Circle ONE): A B

Explain your choice.

…………………………………………………………………
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Appendix B

Instrument-2 of the study

Interview Guide on Students' Understanding of Measurement Uncertainty

NB: before the interview, the SHS3 physics students would be made to respond to closed and open-ended questionnaire items which focus on students' reasons for their choice of responses to the questionnaire items.

SHS3 physics students' understanding of measurement uncertainty of **length** and **time**.

Questions will be asked in respect of students' responses to questions on NU1, and NU2.

Question one is for students who got the item correct

1. You chose this response under NU1 and NU2; why was this response the correct answer?

Question two is for those students who got the item wrong

2. Why did you not choose option B under NU1 and NU2?

Appendix C

Coding Scheme of Students' Responses on Measurement Uncertainty

No Uncertainty 1

NU1 $_{(B)}$: No, that is not possible.

1. Not classified.
2. No explanation given.
3. Because one measurement cannot give the true value, but several measurements with their average gives the true value.
4. Because the speed the ball used to reach d differs from one experiment to the other.
5. Because average cannot be determined by only one measurement. Also if the graph method is to be used one measurement cannot plot the graph and the slope cannot also be determined.
6. Because practicing/experimenting enough/severally can only give very close values but cannot give a perfect value most especially with one measurement.

No Uncertainty 2

NU2 $_{(B)}$: No, it is impossible to have such an experiment.

1. Not classified.
2. No explanation given.
3. Because everything under this sun is physics and for that matter scientist can design such an experiment.
4. Because when you experiment, you get to know the accurate / exact or nearer values.
5. Because physics deals with things that happens as they have proves for everything.
6. Because experiment can be performed under so many conditions which would affect the final results.
7. Because experiment in physics can only be done in the laboratory but not by discussion.
8. Because final experimental results cannot be predicted.
9. Because if such an experiment is done students will develop negative attitudes towards learning such as laziness and lower thinking abilities.
10. Because scientists always work with facts.
11. Because students need to experiment on their own in order to understand scientific measurement.
12. Because all experiment must be proved so that any other person can practice it and understand it.
13. Because of errors and uncertainties associated with every measurement both in the experimental results and experimental setup.