Assessment on Students' Science Process Skills: A Student- Centred Approach

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Abstract

The study was conducted to assess the scientific skills of the selected second year students of Lugait National High School (LNHS) and Naawan National High School (NNHS) S.Y 2011-2012 on their monitoring of the growth of String beans (*Phaseolus vulgaris*). Fifteen second year students in a biology class from both public high schools were chosen as respondents. They were oriented on the procedures used in bio monitoring as well as the rubrics used in assessing their performance such as setting up the equipment, following procedures, data collection, safety and clean up procedure. The performances of students from both schools were the same in terms of observing the colour and texture of the leaves and both have a very good knowledge in the bio monitoring procedures. But they differ in their accuracy and precision in the measurement of the length of the stem, length and width of the leaves of the bio monitored plant. The LNHS students were more accurate while the NNHS students were more precise. The performance of the selected students of both schools in identifying the colour and texture of the leaves do not differ significantly with the researcher ($p>0.05$). Results also showed that the selected LNHS students do not differ with the researcher in the measurements of the length of the stem and length and width of the leaves. Among the 5 parameters used in this student-centred approach scientific experiment in bio monitoring of the *Phaseolus vulgaris*, the selected second year students from both schools were moderately excellent in data collection and excellent in the setting up the equipment, following procedures, safety and precautions and clean up procedure. The student-centred approach doing hands-on activities incorporating inquiry based science teaching to science instruction has significantly improved the students' science process skills.

Key words: scientific skills, bio monitoring, student-centred approach

Introduction

Educators seek ways to meet the demands put upon the educational system in today's world of rapid changes. Educators should adopt changes in the field of teaching by applying varieties of teaching methodologies and strategies that will guide in planning a smooth operation and management of all the elements contributory to students' learning and to improve the quality of education (Mendler & Curwin, 1983).

With the great proliferation of knowledge and rapid changes in the field of Science and Technology as well as the appearance of many new fields, it is critical to develop students' capacity for self-directed learning and self-growth. With this, teachers use different teaching approaches to meet the needs of the students. The conventional teacher-centred approach is focused on the teacher, where the teacher talks and the students just listen while the student-centred approach the students are exposed to hands on activities thus, they will gain first-hand experience, and they will also know how to use all their senses. Students will be able to make keen and reliable observations and develop the skill in employing the steps of scientific method. In this approach, the joy and the pride of discovering are emphasized where students discover what they planned to look for, thus, learning becomes permanent (Salandanan, 2009).

The trend to move away from teacher-centred to a more student-centred approach gave students more opportunity to reflect on their own learning, gain deeper understanding of the science concept and become better critical thinkers (Bain et al., 2005).

The student-centred approach in teaching is also known as child-centred learning (Kember, 2009). It is focused on the students' needs, abilities, interests, and learning styles with the teacher as a facilitator of learning.

The student-centred approach is based on the hypothesis that students who are given the freedom to explore areas based on their personal interests, and who are accompanied in their striving for solutions by a supportive, understanding facilitator not only achieve higher academic results but also experience an increase in personal values, such as flexibility, self-confidence and social skills (Rogers, 1983). This approach allows students to apply information to their own situations, making the learning more meaningful (Aspy, 1972).

The student-centred teaching methods shift the focus of activity from the teacher to the learners. These methods include active learning, in which students solve problems, answer questions, formulate questions of their own, discuss, explain, debate, or brainstorm during class; cooperative learning, in which students work in teams on problems and projects under conditions that assure both positive interdependence and individual accountability; and inductive teaching and learning, in which students are first presented with challenges (questions or problems) and learn the course material in the context of addressing the challenges. The inductive methods of teaching also include inquiry-based learning (IBL), case-based instruction, problem-based learning, project-based learning, discovery learning, and just-in-time teaching (Felder & Brent, 2009).

The inquiry based learning is an instructional method developed during the discovery learning movement of 1960's. It is a form of a student-centred learning where progress is assessed by how well the students develop experimental and analytical skills (Hannafin et al., 1999). In many conventional science experiments, students were told what the outcome of an experiment will be, or expected to be, and the students were simply expected to confirm the results obtained. In a student-centred teaching using IBL, on the other hand, the students are either left to discover for themselves what the result of an experiment is. It also applies an open learning process which has been developed by number of science educators including John Dewey (Bell et al., 2010).

In a student-centred science experiments using IBL, the students are engaged in several processes such as observing, comparing, contrasting and hypothesizing (Cuevas et al., 2005).These activities served as a source of science process skills. In addition, the term inquiry has figured prominently in science education, three distinct categories of activities: what scientist do, how students learn, and a pedagogical approach that teachers employ (Miner, 2010)

From a science perspective, student-centred approach using inquiry-based science teaching engages students in the investigative nature of science. Inquiry involves activity and skills, but focus on the active search of knowledge or understanding curiosity (Ketpichainarong et al., 2002).

In a science experiments using student-centred approach particularly has many benefits. It means students do not simply perform experiments in a routine like fashion, but actually think about the results they collect and what they mean. With traditional non-open lessons there is a tendency for students to say that the experiment 'went wrong' when they collect results contrary to what they are told to expect. In open learning there are no wrong results, and students have to evaluate the strengths and weaknesses of the results they collect themselves and decide their value (Hannafin et al., 1999).

This study aims to evaluate the students' performance in doing science laboratory experiment on the growth of *Phaseolus vulgaris* planted in two study sites. The physical changes of the plant such lengths of stem and leaves, changes in colour of the plant were bio monitored by selected second year high school students of Lugait National High School (LNHS) and Naawan National High School (NNHS) using a student-centred approach particularly inquiry based-learning.

For educators, student- centred approach using inquiry implies emphasis on the development of inquiry skills and the nurturing of inquiring attitudes or habits of mind that will enable students to continue the quest for knowledge throughout life. Content of disciplines is very important, but as a means to an end, not as an end in itself. The knowledge base for disciplines is constantly expanding and changing. No one can ever learn everything, but everyone can better develop their skills and nurture the inquiring attitudes necessary to continue the generation and examination of knowledge throughout their lives. For modern education, the skills and the ability to continue learning should be the most important outcomes (Hubbard, 2001).

Purpose of study

The result of this study will also serve as a tool for the teacher on identifying the strength and weaknesses of the students' performance on the different scientific skills namely, observing, measuring, data gathering and following the procedures systematically. This study was conducted based on the following questions.

1. Is there a significant difference in the students' performance of the selected second year high school students of Lugait National High School and Naawan National High School on the accuracy in measuring the length of the stem, and length and width of the leaves, keen in observing the colour and texture of the leaves and systematic in the application of the procedures used?
2. Is there a significant difference in the observation of the selected second year high school students of Lugait National High School, Naawan National High School and the researcher as the reference on the physical properties like length of the stem and leaves, texture and colour of the leaves of *P.vulgaris* planted in Lugait, Misamis Oriental and Naawan, Misamis Oriental?
3. Is there a significant difference in the performance among and between the selected second year students of Lugait National High School and Naawan National High School in conducting the bio monitoring following the rubrics for conducting laboratory experiment?
4. Is there a significant difference between strength and weaknesses of the student's performance in conducting science laboratory experiment using student- centred approach?

Methodology

Participants

This study was conducted in Lugait National High School and Naawan National High School. The three sections of the second year level in each school were chosen and five students per section were selected by draw lots. Thus, fifteen students from each school, aged 14, regardless of gender performed the bio monitoring of *P.vulgaris* in a period of 15 school days. A total of 30 students served as the subject of the study.

A permission to conduct this study in their school was requested from the school principal of both Lugait National High School (LNHS) and Naawan National High School (NNHS) through a written communication. The list of names of the students was coded to observe confidentiality in manipulating the data. In order for the students to be guided in the bio monitoring of *P.vulgaris* plant, guidelines for scoring the students' performance following the rubrics of conducting laboratory experiment (Blaine, 2003) was thoroughly discussed (Appendix 1).

Bio monitoring the growth of String Beans (Phaseolus vulgaris.)

String beans are used as bio monitored plants because of its sensitivity to soil pH level, anything too acidic or basic prevents uptake of certain nutrients that results to a change in leaf's colour or texture.

The selected students were oriented on the procedure of bio monitoring which included the time when to water the plant, amount of water to be used daily, which leaves to be measured and analysed, and proper use of equipment such as ruler and beaker. Each student was assigned to monitor one *P.vulgaris* planted in one plastic pot. These fifteen plastic pots with *P.vulgaris* were placed inside a cage surrounded with fine-mesh net to protect it from any organisms (Figure 1). The plants were directly exposed to sunlight. Each student has their own journal where they recorded the physical properties of *P.vulgaris* such as the length of the stem and the length, width, colour and texture of the first five leaves. The presence of chlorosis (yellowing of the leaves) and necrosis (browning of the leaves) were also recorded. The researcher did the same bio monitoring as reference in evaluating the students' performance.

Figure 1. *The Phaseolus vulgaris inside the cage enclosed with fine-mesh net.*

Statistical procedure

T-test and ANOVA were used in the statistical analysis. The T-test was used to determine the variation between two groups at 95 percent level of confidence or $p<0.05$. It was used to compare the mean score of the selected Lugait National High School and Naawan National High School second year students in their accuracy of measuring the length of the stem, length and width of the leaves. In addition, T-test was also used to determine the variation of the students' observation on the colour and texture of the leaves and further measures the students' skills in applying and following the procedures used in the bio monitoring of *Phaseolus vulgaris*.

The Analysis of variance (ANOVA) was used to compare the mean score (Appendix 2) obtained by the selected students of Lugait National High School and Naawan National High School and measurements obtained by students and the researcher (Appendix 3) as the point of reference in giving daily scores from their daily performance (Appendix 4).

Rubrics for conducting science laboratory experiment (Blaine,2003) was used in bio monitoring of *P.vulgaris*, this included setting up and caring of equipment (all equipment accurately placed, all necessary supplies on hand and very neat and organized), following procedure (demonstrates very good knowledge of the laboratory procedure, gladly help other students to follow procedures and thoroughly and carefully follows each step before moving on the next step) , data collection (measurements are both accurate and precise, observations are very thorough and may recognize possible errors, work is neat and organized and includes appropriate symbols, units and significant digits), safety (proper safety precautions are consistently used, consistently thinks ahead of time to ensure safety, will often help other students to conduct laboratory safely), and clean up (consistently uses proper clean up procedures, often will help other students to complete task properly and station always left neat and clean).

Results

Performance of the selected students of LNHS and NNHS in measuring the length of stem, length and width of the leaves, observing the colour and texture of the leaves and following the procedures used in bio monitoring

Figure 2 shows the mean score of the selected second year students of LNHS and NNHS in accuracy and precision in measurement, observations skill and following procedures. LNHS students got a higher mean score in accuracy and precision of measurements ranging from 53 to 75 points. On the other hand, lower mean score was observed from the results obtained from the selected students of NNHS ranging from 49 to 71 points. A difference of one point was observed between the mean score of 71 points of LNHS and NNHS (70 points) in their observation skills and another one point difference from the mean score of 74 points for LNHS and NNHS (73 points) in following the procedures used in bio monitoring the growth of *Phaseolus vulgaris*.

A significant difference ($p = 0.00$) was observed among the scores of the students of LNHS in measuring the length of the stem, length and width of the leaves of P. vulgaris. It was also observed (Table 1) that there is a significant difference ($p = 0.00$) between the scores of the selected students of LNHS and NNHS in measuring the length of the stem, length and width of the leaves of the *P. vulgaris*. A significant difference ($p = 0.0$) was observed among the scores of the students of LNHS and NNHS in following the procedures used in bio monitoring.

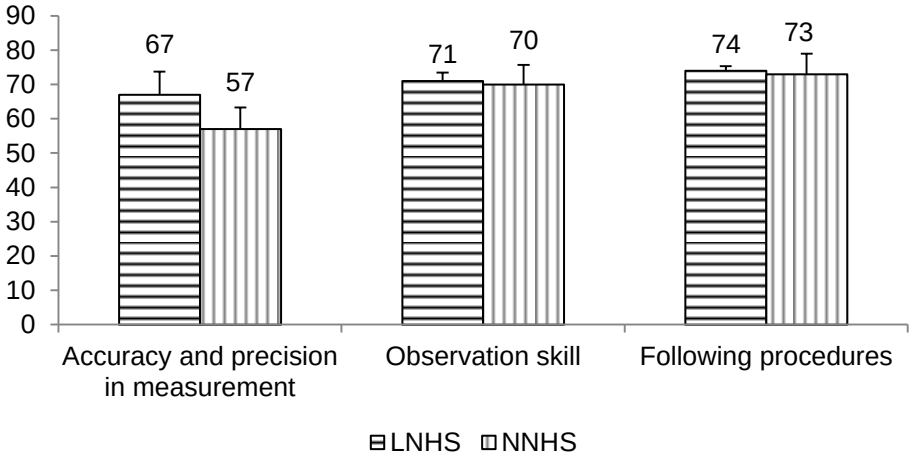

Figure 2. *The mean score of the selected second year students of LNHS and NNHS in accuracy and precision in measurement, observations skill and following procedures.*

On the other hand, no significant difference (p = 0.10) was observed in the scores of the students of NNHS in measuring the length of the stem, length and width of the leaves of the *P. vulgaris*.

Table 1. *Statistical test comparing the performance of the selected students of LNHS and NNHS in measuring the stem, length and width of the leaves, observing the colour and texture of the leaves and following the procedures used in bio monitoring.*

Parameters	***P**-values**		
	Among LNHS students (ANOVA)	**Among NNHS students (ANOVA)**	**Between LNHS & NNHS students (T- test)**
a. Performance in measuring the length of the stem, length and width of the leaves of *Phaseolus vulgaris.*	0.00	0.10	0.00
b. Performance in observing the color and texture of the leaves	0.31	0.10	0.59
c. Performance in following the procedures used in bio monitoring.	9.36	0.00	0.11

* significant at 95% level of confidence at α=0.05

Comparison of the observations on the physical properties of Phaseolus vulgaris planted by the selected second year students of LNHS, NNHS and the researcher as reference

A graph in Figure 3 shows the number of students from LNHS (Black) and NNHS (Orange) who got higher, lower and equal to the reference. As shown in the graph, the selected second year students from LNHS and NNHS got consistently lower measurements in the length of the stem and the length and width of the leaves as compared to the results obtained by the researcher. On the other hand, the selected students from NNHS got very close results with the researcher in observing the presence of necrosis and chlorosis of the leaves.

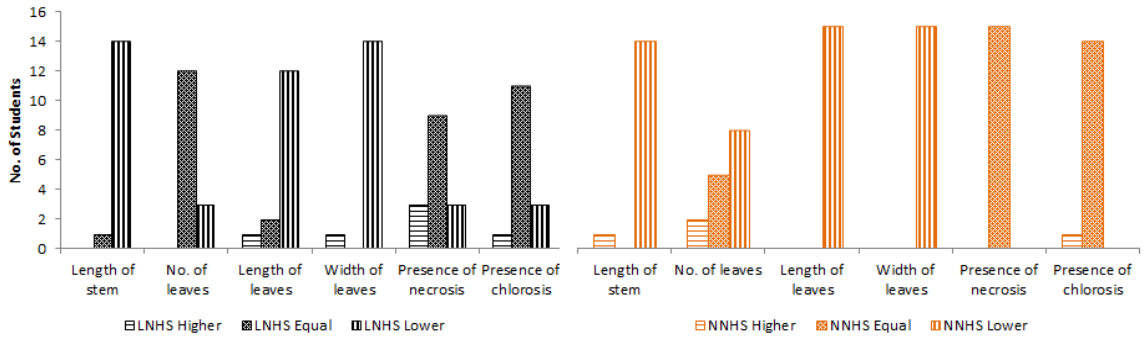

Figure 3. *The number of students from LNHS (Black) and NNHS (Orange) who got higher, lower and equal readings and observations with the reference*

The result of the statistical analysis on the observations fn the physical properties of P. vulgaris planted by the selected second year students of LNHS, NNHS and the researcher as reference is shown in Table 2. It was observed that there is no significant difference (p = 0.56) between the measurements of the length of the stem, length and width of the leaves and observations on the colour and texture of the P. vulgaris leaves measured and observed by the selected students of LNHS and the researcher.

Table 2. *Statistical test comparing the observations on the physical properties of Phaseolus vulgaris planted by the selected second year students of LNHS, NNHS and the researcher as reference.*

Physical properties *of Phaseolus vulgaris*	**(T-test) P* values LNHS vs Reference**	**(T-test) P* values NNHS vs Reference**
Length of the stem (mm)	0.56	0.02*
Number of leaves	0.15	0.02*
Length of the leaves (mm)	0.63	0.02*
Width of the leaves (mm)	0.16	0.01*
Presence of necrosis	0.86	0.86
Presence of chlorosis	0.60	0.33

* significant at 95% level of confidence at α=0.05

On the other hand, a significant difference was observed (p = 0.02) between the measurements of the length of the stem, length and width of the leaves (p = 0.02) and the number of leaves appeared (p =0.02) as observed by the selected students of NNHS and the researcher. On the contrary, no significant difference (p = 0.3) was observed on the observations of the colour and texture (p = 0.86) of the leaves observed between the selected students of NNHS and the researcher as reference.

Meanwhile no significant difference p = 0.56 were observed between the measurements of the length of the stem, length and width of the leaves (p = 0.15), number of leaves appeared (p = 0.63), presence of necrosis (p = 0.86)and necrosis (p = 0.60) observed by the selected students of LNHS and the researcher.

Statistical test comparing the scores among and between the selected second year high school students of LNHS and NNHS in conducting laboratory experiments used in bio monitoring of Phaseolus vulgaris

Table 3 shows the results of the statistical analyses showing the mean score of the selected LNHS and NNHS in the rubrics for conducting laboratory experiments used in bio monitoring of *P. vulgaris*. The result shows a significant difference ($p < 0.05$) between the mean scores of the selected second year students of LNHS and NNHS in setting up and caring of the equipment, following procedures and data collection. Meanwhile no significant difference was observed ($p > 0.05$) in safety and cleans up criteria in the rubrics of conducting laboratory experiment.

Table 3. *Statistical test on the scores of the selected students of LNHS and NNHS in conducting a laboratory experiment used in bio monitoring.*

Criteria	P^* - value among the LNHS students (ANOVA)	P^* - value among the NNHS students (ANOVA)	P^* - value between LNHS and NNHS students (T-Test)
1. Set up and equipment care	0.06	3.70	0.01*
2. Following procedures	9.36	0.00*	0.11
3. Data collection	0.00*	0.00*	0.05*
4. Safety	ns	ns	ns
5. Clean up	ns	ns	ns

* significant at 95% level of confidence at α=0.05 ns – means not significant

Strength and weaknesses of the selected second year students of LNHS and NNHS conducting a science laboratory experiment

Figure 4 shows the strength and weaknesses of the selected second year students of LNHS and NNHS in conducting a science laboratory experiment which is bio monitoring of *P.*

vulgaris. The selected students from LNHS and NNHS both got highest score in safety and clean up procedures with the highest score of 75 points while the common weakest area in both schools is data collection with 64-66 points.

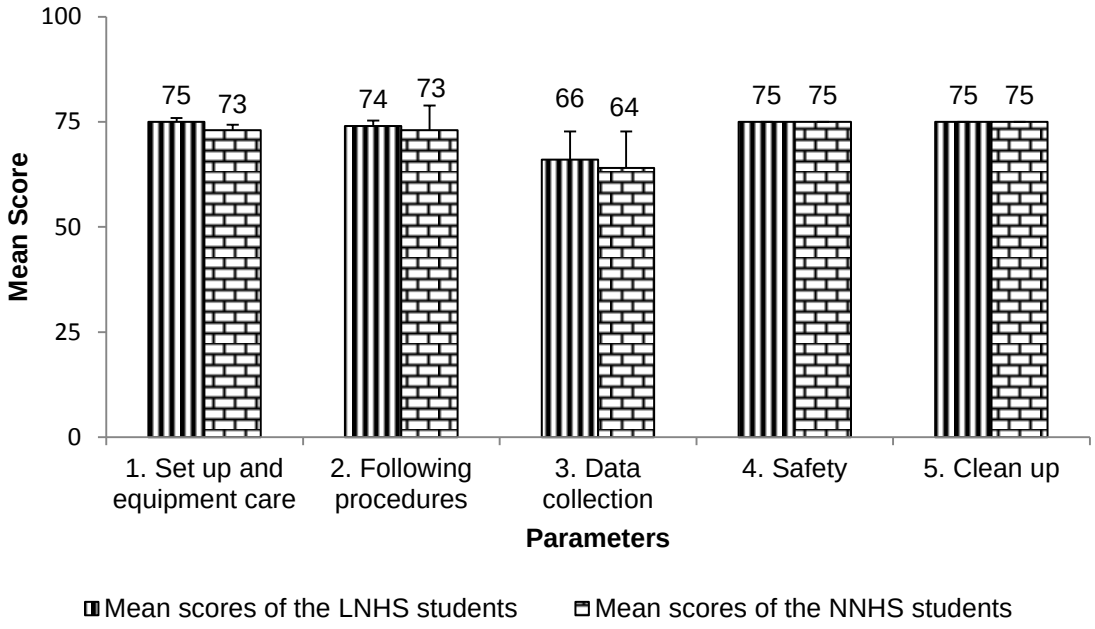

Figure 4. *The mean score obtained by the selected second year high school students of LNHS and NNHS in the different parameters in conducting a science laboratory experiment.*

Discussion

Performance of the selected students of LNHS and NNHS in measuring the length of stem, length and width of the leaves, observing the colour and texture of the leaves and following the procedures used in bio monitoring

The scores obtained by the selected LNHS students in measuring the length of the stem, length and width of the leaves of the plants they bio monitored ranged between 61 to 75 points. However, a significant difference ($p = 0.00$) was observed in the mean scores of the LNHS students. This significant difference in their scores indicated that the measurements done by these students were accurate with reasonable precision (Appendix 4).

Meanwhile, the difference in scores of NNHS in measuring the length of the stem, length and width of the leaves of the plants they bio monitored was not significant ($p =0.10$). This is an indication that their measurements were precise and moderately accurate.

The range of scores obtained by the LNHS students (61-75) is significantly higher ($p = 0.00$) than the scores (49-71) obtained by the selected NNHS students. Very noticeable from the submitted journals that only one from the fifteen selected LNHS students got a perfect

score of 75 or a measurement that perfectly coincided with the reference while no one from NNHS got the same reading as the reference. This result simply showed that the accuracy of students from LNHS in measuring the length of the stem, length and width of the leaves of the plants they bio monitored was significantly higher than the accuracy of the students from NNHS.

There are many reasons why poor precision in a scientific measurement may arise. One of this is human error. If the person is tired, pre-occupied, inability of the eyes to read the exact calibration of the apparatus and misuse of the instrument may contribute to the accuracy of the measurements (Panisi & Kimlin, 1999). Many of the students from LNHS and NNHS were always in a hurry which was very clear in their actions, some were busy with some requirements from other subject matter and some showed lack of interest.

The LNHS selected students scored from 68 to 75 points in observing the colour, texture and number of leaves appeared in P. vulgaris in their study site. While the selected second year students from NNHS scored ranging from 62 to 75 points. It was also observed that 20% (3 students) and 53% (8 students) of the students from LNHS and NNHS, respectively, got a perfect score of 75 points or has the same observations as the reference. Despite these differences in points observed in both schools, the result of the statistical test ($p = 0.59$) among the scores of the selected students of LNHS and NNHS showed no significant difference. This indicates that students from LNHS performed in the same manner in observing the colour and texture of the bio monitored plants as the students from NNHS.

In a student-centred approach, a variety of hands-on activities are administered in order to promote the different scientific skills such as their skill in observing and skills in measuring The ability to accurately observe and notice small details is important to scientist (Sterling and Hall, 2000). Allowing students to record and share observations, successively focusing in on smaller, more precise details will improve their skills on observing. The students can extend their knowledge in science by carefully noting changes in colour, texture, asking questions and making predictions. Outdoor classroom or learning environment would be a great way to encourage the development of observational and recording skills of the students (Hokkanen, 2011).

The mean score of (71-74) was obtained by the selected LNHS students in following the procedures used in bio monitoring. It was also noted that no student got a perfect score in following the procedures used in bio monitoring. However, precision on the way they followed the procedures was noted as shown from the result of the statistical analysis. The P value obtained is equal to 9.36 which indicates that the score obtained by each student from LNHS do not differ significantly, thus, precision exist.

Meanwhile, 47% from the selected students from NNHS demonstrated a very good knowledge of the bio monitoring procedures. Additionally, 7 out of the 15 NNHS students got a perfect score in following the procedures. The mean score obtained by the selected NNHS students ranged from 51 to 75 points. The differences from the scores of the selected second year students from NNHS were found to be significant ($p = 0.00$). This could be attributed to the wider range (51-75) of score obtained by the students.

It is worthwhile to note that despite these differences in points obtained by the LNHS students (71-75) and NNHS students (51-75), the result of the statistical test ($p = 0.1$)1 showed no significant difference. This indicates that students from LNHS and NNHS similarly followed the procedures in bio monitoring the growth of *P. vulgaris*.

In a student-centred approach, learning can be seen as a form of personal growth, students are encouraged to utilize self-regulation practices such as following class instructions or procedures, motivating oneself to do school work and participating class discussion (Dweck & Master, 2008). Procedures and routines are the backbone of daily classroom life, because they are statements of student's expectations necessary to participate successfully in classroom activities, to learn and to function effectively in school (De Mers, 1998).

Comparison of the observations on the physical properties of Phaseolus vulgaris plant by the selected second year students of LNHS, NNHS and the researcher as reference

The selected students from LNHS reported that the plants they bio monitored have stems' length ranging from 168 to 242 mm. This range of the stem is very close to the measurement observed by the researcher ranging from 172 to 292 mm. It was noted that, one of the 15 students got the same measurements with the researcher. The statistical test comparing the observations of the selected students from the LNHS and the researcher $p = 0.56$ showed no significant difference.

However, a wider range of stems' length measurement of 1.6 mm to 260 mm was reported by the selected 15 students from NNHS. This range of the length of the stem is far from the measurement observed by the researcher ranging from 102 mm to 263 mm. Thus, resulting to a significant difference between the readings of the NNHS students and the reference ($p = 0.02$). In addition, no one from the selected students got the same results with the researcher.

Accordingly, many students have poor observation and measuring skills due to lack of diligence and patience. Improving scientific skills require diligence and patience (Wilson, 1996). Furthermore, in the case of NNHS students, since the researcher is not their subject teacher, there is a tendency for them to take for granted the bio monitoring procedure. It could also be due to the schedule of the bio monitoring which is done daily and they have other subject requirements to comply.

It was also observed that 73% of LNHS and 20% of NNHS selected second year students coincided with the results obtained by the researcher in counting the number of leaves in the plants they bio monitored. A contradicting statistical test result was obtained in this parameter; at $p = 0.15$ (LNHS vs. reference) and $p = 0.02$ (NNHS vs. reference). This result implies that greater number of students from LNHS got the same results with the researcher in counting the number of leaves appeared in P. vulgaris than those from NNHS.

The selected second year students from LNHS reported also that the plants they bio monitored have leaves with length ranging from 60 to 95 mm and the width ranging from 31 to 50 mm. This range of the leaf measurement is very close to the measurement observed by

the researcher ranging from 62 to 94 mm and the width ranging from 34 to 48 mm. Thereby giving a statistical test result showing no significant difference ($p = 0.63$) in the results obtained from the selected LNHS and the researcher.

On the other hand, the selected second year students from NNHS reported that the plants they bio monitored have leaves with length ranging from 2 to 90 mm and the width ranging from 1.7 to 47 mm which is significantly lower than $p = 0.02$ compared to the measurements obtained by the researcher which is 44 to 92 mm.

Accuracy in measurement has something to do with using a proper calibration values. It is important to closely follow the instructions for the use of calibrator values. The students who were not exposed to measuring equipment (e.g. ruler) may find it confusing on which particular calibration is to be used. In the case of NNHS students, their result has a significant difference to the results obtained by the researcher because 27% (4 students), got a mistake (Appendix 4) in the units used in their measurements. Disregarding the instructions and selecting the wrong calibrator values will produce significant errors (Isherwood et al., 1972) thus affecting accuracy of measurements

It was observed that 9 out of 15 selected students from LNHS got the same results with the researcher in observing the presence of necrosis on the leaves of P. vulgaris in their study sites, while all of selected students from the NNHS got the same results with the researcher. The statistical test ($p = 0.86$) comparing the results obtained by the selected students from LNHS and NNHS with the researcher showed no significant difference.

Meanwhile, a 10 and 14 out of 15 selected students from LNHS and NNHS, respectively, got the same results with the researcher. The result of the statistical analysis ($p = 0.60$) and ($p = 0.33$) comparing the results obtained by the selected students from LNHS and NNHS with the researcher shows no significant difference.

The results obtained in this study is a very good indication of the positive outcomes of student-centred approach. Accordingly, student-centred approach allows students to actively participate in discovery learning processes. For learning by doing, students use almost all of their senses and learning becomes more permanent and hands-on activities get them to acquire experiences. Letting the students engage in more science activities and exercises will develop their scientific skills in observing, comparing, contrasting and hypothesizing (Ergul, 2011). When science processed skills are emphasized in the classroom, student proficiency on individual skills increases and retained over time. In a student-centred approach, the students are personally involved in planning the learning activity, especially the procedures to be followed. They experience manipulating the measuring device or equipment. The students learn best from their experiences. It is essentially a way of acquiring knowledge of skills through direct and keen observations followed by analysis of what has been sensed and understood (Markel, 1999).

Statistical test comparing the scores among and between the selected second year high school students of LNHS and NNHS in conducting laboratory experiments in bio monitoring of Phaseolus vulgaris

The LNHS selected students scored ranging from 72 to 75 points or an average score of 73 points in setting up and caring of equipment used during the bio monitoring of *Phaseolus vulgaris*. While the selected NNHS students scored ranging from 71-75 points. It was also observed that 67% (10 students) and 27% (4 students) of the selected students from LNHS and NNHS, respectively, got a perfect score of 75 points. The result of the statistical test that shows no significant difference among the scores among the students of LNHS ($p = 0.06$) and NNHS ($p = 3.70$)indicated that applying the student-centred approach in the bio monitoring experiment students from both school were able to set and care the equipment appropriately.

The selected students from LNHS scored ranging from 71 to 75 in following the procedures used in bio monitoring, while the selected students from NNHS scored ranging from 51-75 points. It was also observed that there is no student from LNHS and 2 students from NNHS got perfect (75 points) in following the procedure. No significant difference ($p = 9.36$) was observed among the scores obtained by the selected LNHS students. However, a significant difference ($p = 0.0$) was observed in the scores obtained by the selected NNHS students. Despite these differences in points observed in both schools, the result of the statistical test ($p= 0.11$) between two schools was not significant. Rubrics analysis on this result pointed out that the students in both schools showed a very good demonstration of knowledge of the laboratory procedures, they gladly help their classmates to follow procedures thoroughly and carefully followed each step before moving on to the next step.

The score obtained by the selected LNHS students in data collection during the bio monitoring of P. vulgaris ranged between 51 to 75 points while the selected NNHS students scored ranging from 49 to 75 points. This result indicated the presence of precision on the way both students from LNHS and NNHS collected their data as also shown in the results of the statistical analysis ($p = 0.00$). Rubrics' analysis in their scores in data collection showed that there was accuracy and precision in their measurements, their observations were very thorough, they have recognized possible errors, and they gave neat and organized results that included appropriate symbols, units and significant digits.

One hundred percent (15 students) of both LNHS and NNHS got 75 points in safety and precautions. The results affirmed the findings that student-centred approach in a form of science experiments shows an important part of the student's education. Students should also use science experiments as a way to learn basic safety precautions (Soden, 2012). In fact, learning and utilizing safety rules during science experiments should be a team process. Most importantly, teachers should be present with the students during all science experiment not just a role model but to supervise as well. In a student-centred approach, students can play an active, responsible role in maintaining safe science laboratory. Furthermore, the performance of the selected students in both schools showed that they consistently observed proper safety precautions and often help other students to ensure laboratory safely.

Similarly,100% (15 students) of both LNHS and NNHS students got a perfect 75 points in clean up procedure. This implies that applying student-centred approach, the students from both schools were able to show consistently the use of proper clean up

procedure, often help other students to complete task properly and their work area were always left neat and clean.

Strength and weaknesses of the selected second year students of LNHS and NNHS in conducting a science laboratory experiment

It is good to note that applying student-centred approach particularly Inquiry Based Learning in conducting science experiment in selected students from LNHS and NNHS showed that among the 5 parameters evaluated the students showed moderately excellent in data collection only. This parameter can be considered as their weak area. All of them are excellent in the other 4 parameters as also shown by the 75 points (perfect score) they obtained in safety and precautions; 75 points in clean-up procedures; 74.5 in setting up and equipment care; and 73.5 in following procedures used in bio monitoring.

Students are naturally curious about the world around them. Young minds are best suited to learn through hands-on experimentation. Involve students in science activities that encourage exploration and questioning. One of the best things about student-centred approach is that it nurtures and develops the learner's conceptual framework. This framework is the foundation of the students to learn more detailed and specific knowledge (Armstrong, 2012).

Conclusion

The following conclusions are formulated based from the results obtained by the study:

1. The selected second year students from LNHS are accurate in measuring the length of the stem, length and width of the leaves of the bio monitored plant while NNHS students were found precise in measurement.
2. The selected students from both schools performed in the same manner in observing the colour and texture of the leaves of the plants being bio monitored and they have exhibited a very good knowledge in the bio monitoring procedure.
3. The selected second year students from LNHS and NNHS got consistently, lower measurements in the length of the stem, length and width of the leaves of the P. vulgaris as compared to the researcher. However, the students from LNHS got very close result with the researcher in observing the presence of necrosis and chlorosis of the leaves.
4. Among the 5 parameters used in a student-centred approach scientific experiment in bio monitoring of the *P.vulgaris*, both the selected second year students from LNHS and NNHS are moderately excellent in data collection. This parameter can be considered as their not so strong area while all of them are excellent in the other 4 parameters.
5. Applying student-centred approach in a science experiment will develop the students' scientific skills in observing and measuring. Students experienced manipulating the measuring device or equipment and were personally involved in data collection. The student-centred approach enhances personal growth and encourages students to utilize self-regulation like following class instruction or procedure.

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Appendices

Appendix 1. *Rubrics for conducting science laboratory experiment (Blaine, 2003)*

Criteria	1	2	3	4	5
Set-up and Equipment Care	• Set-up of equipment is not accurate, help is required with several major details • Many necessary supplies must found in mid-lab	• Set-up of equipment is generally workable with several details that need refinement • Some necessary supplies must be searched out	• Set-up of equipment is generally accurate with 1 or 2 small details that need refinement • All necessary supplies on hand	• All equipment accurately placed • All necessary supplies on hand	• All equipment accurately placed • All necessary supplies on hand • Very neat and organized
Following Procedure	• Lacks the appropriate knowledge of the lab procedures • Often requires help from the teacher to even complete basic procedures	• Demonstrates general knowledge of lab procedures • Requires help from teacher with some steps in procedures	• Demonstrates good knowledge of the lab procedures • Will ask peers for help with problems in lab procedures • Works to follow each step before moving on to the next step	• Demonstrates sound knowledge of lab procedures • Will discuss with peers to solve problems in procedures • Carefully follows each step	• Demonstrates very good knowledge of the lab procedures • Gladly helps other students to follow procedures • Thoroughly and carefully follows each step before moving on to next step
Data Collection	• Measurements are incomplete, inaccurate and imprecise • Observations are incomplete or not included • Symbols,units and significant figures are not included	• Measurements are somewhat inaccurate and very imprecise • Observations are incomplete or recorded in a confusing way • There are 3 or more minor errors using symbols, units and significant digits or 2 major errors	• Measurements are mostly accurate • Observations are generally complete • Work is organized • Only 2 or 3 minor errors using symbols, units and significant digits	• Measurements are accurate with reasonable precision • Observations are thorough • Work is generally neat and organized • Includes symbols, units and significant digits	• Measurements are both accurate and precise • Observations are very thorough and may recognize possible errors in data collection • Work is neat and organized • Includes appropriate symbols, units and significant digits
Safety	• Proper safety precautions are consistently missed • Needs to be reminded often during the lab	• Proper safety precautions are often missed • Needs to be reminded more than once during the lab	• Proper safety precautions are generally used • May need to be reminded once during the lab	• Proper safety procedures are consistently used • Uses general reminders of safe practices independently	• Proper safety precautions are consistently used • Consistently thinks ahead to ensure safety • Will often help other students to conduct labs safely
Clean-up	• Proper clean-up procedures are seldom used • Often requires help to complete clean-up 3 or more items left at station or station not cleaned	• Needs to be reminded more than once during the lab to use proper clean-up procedures • 1 or 2 items left at station or not cleaned	• Proper clean-up procedures generally used • May need some help on occasion to complete tasks • Station generally left clean	• Consistently uses proper clean-up procedures • Station generally neat and clean	• Consistently uses proper clean-up procedures • Often will help other students to complete tasks properly • Station always left neat and clean

Appendix 2. *Mean score of the selected second year students of LNHS in bio monitoring the Phaseolus vulgaris.*

	Study site 1 (Lugait National High School (L1 - L15)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	Mean Score
	Criteria / Student's Performance Evaluation Guide																
A.	Set-up and Equipment																
	1.All equipment accurately placed	75	75	73	74	75	75	75	75	75	75	75	73	73	75	72	75
	2.All necessary supplies on hand	75	75	73	74	75	75	75	75	75	75	75	73	73	75	72	75
	3. Vey neat and organized	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	75
B.	Following Procedure																
	1. Demonstrates very good knowledge of the lab procedures	74	72	71	71	74	73	73	73	73	73	72	72	72	72	72	73
	2.Gladly helps other students to follow procedures	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Thoroughly and carefully follows each step before moving on to next step	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	74
C.	Data Collection																
	1.Measurements are both accurate and precise	63	61	57	53	61	73	68	66	75	71	71	68	73	73	73	67
	2. Observations are very thorough and may recognize possible errors in data collection	69	70	70	70	69	69	68	68	75	75	71	71	72	71	75	71
	3. Work is neat and organized	72	70	70	65	68	59	56	69	71	66	69	66	65	65	66	67
	4. Includes appropriate symbols, units and significant digits	67	67	64	68	68	67	58	51	51	51	74	52	71	62	50	62
																	66
D.	Safety																
	1.Proper safety precautions are consistently used	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	2. Consistently thinks ahead to ensure safety	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Will often help other students to conduct labs safely	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	75
E.	Clean-up																
	1.Consistently uses proper clean-up procedures	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	2.Often will help other students to complete tasks properly	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Station always left neat and clean	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	Total																75

Appendix 3. *Mean score of the selected second year students of NNHS in biomonitoring the Phaseolus vulgaris.*

	Study Site 2 (Naawan National High School) N1 - N15	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	Mean Score
	Criteria / Student's Performance Evaluation Guide																
A.	Set-up and Equipment																
	1.All equipment accurately placed	72	75	73	73	75	72	73	72	72	73	74	74	75	71	75	73
	2.All necessary supplies on hand	72	75	73	73	75	72	73	72	72	73	74	74	75	73	75	73
	3. Vey neat and organized	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	73
B.	Following Procedure																
	1. Demonstrates very good knowledge of the lab procedures	75	69	75	75	75	62	75	63	74	75	75	62	65	51	51	68
	2.Gladly helps other students to follow procedures	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Thoroughly and carefully follows each step before moving on to next step	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	73
C.	Data Collection																
	1.Measurements are both accurate and precise	63	55	71	62	57	53	63	64	58	50	49	58	57	51	51	57
	2. Observations are very thorough and may recognize possible errors in data collection	66	68	75	75	75	75	75	75	75	63	62	75	65	63	63	70
	3. Work is neat and organized	73	75	65	66	70	60	66	68	63	52	59	54	57	58	58	63
	4. Includes appropriate symbols, units and significant digits	74	75	75	73	73	61	63	50	49	52	49	56	59	75	75	64
																	64
D.	Safety																
	1.Proper safety precautions are consistently used	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	2. Consistently thinks ahead to ensure safety	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Will often help other students to conduct labs safely	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
																	75
E.	Clean-up																
	1.Consistently uses proper clean-up procedures	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	2.Often will help other students to complete tasks properly	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	3.Station always left neat and clean	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	Total																75

Appendix 4. *Bio monitoring results of the selected second year students of LNHS (Study site 1), NNHS (Study site 2) and the researcher.*

	Length of the stem (mm)				Number of leaves appeared				Length of the leaves (mm)				Width of the leaves (mm)				Presence of necrosis				Presence of chlorosis			
	Study site 1		Study site 2		Study site 1		Study site 2		Study site 1		Study site 2		Study site 1		Study site 2		Study site 1		Study site 2		Study site 1		Study site 2	
	LNHS	Reference	NNHS	Reference	LNHS	Reference	NNHS	Reference	LNHS	Reference	NNHS	Reference	LNHS	Reference	NNHS	Reference	LNHS	Reference	NNHS	Reference	LNHS	Reference	NNHS	Reference
Plant 1	210	217	122	226	8	8	8	8	60	62	75	78	40	42	39	40	3	2	0	0	0	0	3	0
Plant 2	225	231	134	146	8	8	5	8	83	85	24	44	42	45	13	27	2	0	0	0	1	2	0	0
Plant 3	200	211	83	192	8	8	6	7	69	72	65	68	33	35	35	38	3	1	0	0	0	1	0	0
Plant 4	215	221	95	102	8	8	6	8	75	79	33	48	50	47	16	27	2	2	0	0	3	3	0	0
Plant 5	210	210	110	212	8	8	8	8	71	75	60	88	43	46	42	44	0	0	0	0	0	0	0	0
Plant 6	187	191	220	224	9	9	7	8	68	72	80	84	41	43	45	48	0	0	0	0	0	0	0	0
Plant 7	167	172	131	140	8	8	5	8	67	71	60	64	40	45	38	41	0	0	0	0	1	1	0	0
Plant 8	189	194	126	142	10	10	7	8	63	64	65	71	31	34	45	62	0	1	0	0	0	0	0	0
Plant 9	200	211	200	120	8	8	8	8	79	79	90	92	41	44	47	52	0	1	0	0	0	0	0	0
Plant 10	290	292	260	263	8	8	5	8	91	94	40	55	42	45	30	48	0	0	0	0	0	2	0	0
Plant 11	200	210	1.6	166	5	8	9	8	70	72	2	74	35	39	3.8	53	0	2	0	0	0	0	0	0
Plant 12	212	219	160	164	8	9	9	8	73	78	85	86	35	39	38	40	0	0	0	0	3	2	0	0
Plant 13	245	251	120	128	8	8	5	9	88	88	4	49	43	44	2	24	0	0	0	0	0	0	0	0
Plant 14	242	246	1.6	172	7	8	9	9	82	83	2	64	42	43	3.5	39	0	0	0	0	0	0	0	0
Plant 15	230	240	8.2	186	5	8	8	8	95	86	3.5	84	45	48	1.7	52	0	0	0	0	0	0	0	0

Appendix 5. *Photos taken during the bio monitoring of String beans (Phaseolus vulgaris).*

Orientation of the selected second year students of Lugait National High School and Naawan National High School on the rubrics used in following the procedures of the bio monitoring

Figure 5. *The 15 selected second year students from LNHS (left) and NNHS (right)*