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RESEARCH ARTICLE

The Use of Statistical Investigation in Assessing Students' Performance in Statistics

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The recent implementation of adding two additional years (grades 11 and 12) to the kindergarten and grades 1 to 10, now known as the K-12 curricula brought changes in the Philippine educational system. Among these changes is the inclusion of Statistics in the Mathematics curriculum. In previous years, statistics was not a mandatory subject in high school or in higher education, but statistics is now required from preschool to grade 11 of the Science, Technology, Engineering and Mathematics (STEM) track in Senior High School. The purpose of this action research is to develop an understanding of the students' experiences by looking at their statistical understanding and performance during the statistical investigation in order to improve the teaching and learning process of teaching Statistics. Students' level of statistical understanding and performance were mapped based on the Guidelines for Assessment and Instruction in Statistics Education (GAISE) framework. Each of the 11 groups used different worksheets as their guide in every phase of the activity. The teacher-researcher gathered data from classroom encounters using observation field notes, students' written reports, achievement test results, and one-on-one interviews. Findings show a majority of students had very low level of statistical understanding and performance. The merits students gained from the experience, and the challenges they experienced in the statistical investigation were identified. The results can serve as points of reflection and recommendations to improve the teaching practice of Statistics in the next cycle of the action research.

Keywords: statistical investigation; GAISE framework; statistical understanding, statistical reasoning, statistical performance

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Introduction

The recent implementation of adding two additional Senior High School (SHS) grade levels in the Basic Education known as the K-12 curricula brought changes in the Philippine educational system. The entry age in the Kindergarten is five years old and the average age of a SHS graduate is eighteen years old. Statistics in the old K to 10 curriculum was not mandatory but it is now being taught not only in higher education but in every grade level from preschool up to Grade 11 of the Science, Technology, Engineering and Mathematics (STEM) track in Senior High School. Moreover, the teaching of Statistics in the old curriculum was focused merely on computation and the use of formula. The K-12 curriculum included standards that require Statistics be applied in critical thinking, problem solving, reasoning, communicating and decision making in real life.

Statistics, often called data analysis and probability, is now considered an important component of the K to 12 curriculum. With the advent of technology, easier access to data sources and analysis can pave the way to the improvement of statistics teaching. Statistics has evolved from menial routine computation into an investigative process. The focus of statistics curriculum is now shifting from the mastery of statistical skills towards reasoning and thinking statistically (Burgess, 2006).

As Rumsey (2002) posits, any introductory statistics course should develop the good 'statistical citizens' among students by raising their awareness of data in real-life in this information age, and 'research scientist skills' by promoting the use of the scientific method, i.e., developing their ability to identify questions, collect evidence or data, discover statistical tools to interpret the data, and interpret the results. Rumsey (2002) further espoused that in order for students to be able to explain, decide, judge, evaluate, and make decisions about the information, these require statistical reasoning and thinking.

In this modern-day society, it is inevitable that everybody should have basic knowledge in statistics by the time they graduate from high school. From day to day activities such as browsing the internet and assessing current trends, an individual is expected to possess basic statistical literacy. Statistical literacy is the ability to evaluate and comprehend events given a set of data, including the ability to appreciate the influence of statistical thinking in professional, personal, public and private decisions (Wallman, 1993). Statistics is the science of collection, analysis, interpretation or explanation, and presentation of data (Wilson, 2017). Statistics enhances essential skills, such as thinking critically and scientifically, making decisions in the presence of uncertainty, and assessing risks. As the public becomes data intense and information led, statistical thinking skills become necessary for today's citizens (National Council of Teachers of Mathematics, 2016). Specifically, in science, statistical inference tools have helped foster a new ideal of objectivity in establishing scientific knowledge (Porter, 1996, as cited in Parolini, 2015).

Around 1990, a strong plea from prominent statisticians emerged to enhance students' statistical understanding. This plea resulted to the American Statistical Association (ASA) setting the agenda for the future of statistics education by promoting three elements of practice: emphasize statistical thinking; use more data and concepts, less theory and recipes; and foster active learning. By 2000, statisticians have responded to the call to focus future studies on statistical thinking,

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literacy, and reasoning (Ben-Zvi, 2004). In particular, ASA released the report on the Guidelines for Assessment and Instruction in Statistics Education (GAISE) in 2005, which contain a proposed framework that promotes an investigative approach in statistical problem solving grounded on real-world issues. A statistical investigation is an approach which seeks meaning to learn about any aspect of the real world.

Statistical investigation now has become the response of statisticians in the teaching and learning of statistics. It is anchored on real world situations and is undertaken to seek meaning about observed phenomena. Statistics offers other fields of study a set of ideas and tools for dealing with data. The need for this discipline arises from the presence of variability in its application (Cobb & Moore, 1997). According to Cobb and Moore (1997), "Statistics requires a different kind of thinking, because data are not just numbers, but with a context. In mathematics, context obscures structure. In data analysis, context provides meaning." By conducting a statistical investigation, students not only improve in terms of statistical skills, but also improve their statistical reasoning and literacy as well.

These led the researchers to reintroduce statistics as a subject anchored on real-world problems and its solution. In this regard, a statistical investigation was used as the link to real life situations and this study explored the processes students went through as they completed the statistical investigation and to show the development of students' project in every process. Hence, the study aimed to see what was manifested within the context of a statistical investigation and how these can eventually affect teacher's practices. The implementation theory of this action research was to use the GAISE framework in assessing students' statistical understanding of statistical investigation. Specifically, it sought to answer the following questions:

In each phase of the statistical investigation,

1. How do students conduct the statistical investigation?
2. What are the students' level of statistical understanding?
3. What are the merits and challenges encountered by the students?

The GAISE Framework

Franklin and Garfield (2006), published a report that addresses the critical recommendations of the ASA. The GAISE framework consists of the statistical investigation or problem solving process originated from Wild and Pfannkuch's (1999) Problem, Plan, Data Analysis and Conclusion (PPDAC) Model. See **Figure 1** below.

There are four dimensions in Wild and Pfannkuch's framework for statistical thinking namely: (1) Investigative Cycle, (2) Types of Thinking, (3) Interrogative Cycle, and (4) Disposition. The PPDAC model falls under the Investigative cycle where abstraction and solving a statistical problem is anchored on solving a real problem. A knowledgeable solution to a real problem

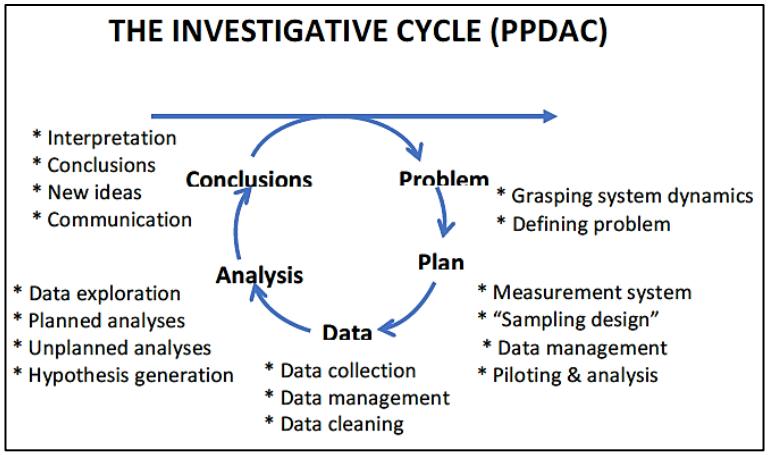

Figure 1. Problem, Plan, Data, Analysis, and Conclusion (PPDAC) Model by Wild and Pfannkuch (1999)

requires better understanding of the situation and how the solution is changed based on a new input from the environment. The process of statistical investigation has five processes: identifying a problem, planning for the procedures to carry out the study, data collection, analyzing the collected data, and the conclusions about the enquiry. This model shows that statistical investigation is iterative, the processes are interconnected and dynamic.

The GAISE contains an outline of a curriculum framework for achieving statistical literacy. The framework consists of two dimensions- the processes of statistical problem solving and developmental levels of statistical understanding and performance. Please see Table 1. The four components of statistical problem solving are consistent with the National Council of Teachers of Mathematics (NCTM, 2000) standards for Data Analysis and Probability. These components are formulating questions, collecting data, analyzing data and interpreting results. As opposed to the cyclical nature of the PPDAC model, the GAISE is linear. The first phase of GAISE, which is formulating questions, is the merging of the plan and problem processes of the PPDAC. An additional component of the GAISE framework is the focus on understanding variability and its impact on the collection, analysis, and interpretation of data (Metz, 2010). The three developmental levels of statistical understanding, Level A, Level B, and Level C, with Level C as the highest and more desirable, outline the developmental progression of statistical understanding and performance students must experience to become statistically literate.

As a framework that describes statistics as an investigative process, the salient point of the GAISE is in providing student experiences and opportunities to be successful at learning statistical concepts when statistics is applied in research or problem solving.

Table 1. The GAISE Framework (Franklin & Garfield, 2006)

Process Component	Level A	Level B	Level C
Formulate Question	Beginning awareness of the statistics question; Low level of distinction; Teachers posed the questions of interest; Questions are restricted to the classroom.	Increased awareness of the statistics question; Average level of distinction; Students begin to pose their own questions of interest; Questions are not restricted to the classroom.	Students can make their own statistics question; There is high level of distinction; Students pose their own questions of interest; Questions seek generalization.
Collect Data	Students cannot design yet for differences; Use of classroom census; Simple experiment;	Beginning awareness of design for differences; Sample surveys; Begin to use random selection and allocation; Comparative experiment.	Students design for differences; Sampling designs with random selection and allocation; Use of more appropriate experimental designs.
Analyze Data	Use particular properties of distributions in the context of a specific example; Display variability within a group; Compare individual to individual; Beginning awareness of group to group; Observe association between two variables.	Learn to use particular properties of distributions as tools of analysis; Quantify variability within a group; Compare group to group in displays; Acknowledge sampling error; Use of some quantification of association or simple models of association.	Use distributions in analysis as a global concept; Measure variability within and between groups; Compare group to group using displays and measures of variability; Describe and quantify sampling error; Quantifies association and/or fitting of models for association.
Interpret Results	Failure to look beyond data; No generalization beyond the classroom; Note difference between two individuals with different conditions; Observe association in displays.	Acknowledge that looking beyond the data is feasible; Acknowledge that a sample may or may not be representative of the larger population; Note the difference between two groups with different conditions Aware of distinction between observational study and experiment Note differences in strength association Basic interpretation of models for association Aware of the distinction between association and cause and effect	Results are beyond the data in some contexts; Generalize from sample to population; Aware of the effect of randomization on the results of experiments; Understand the difference between observational studies and experiments Interpret measures of strength of association Interpret models of association Distinguish between conclusions from association studies and experiments

A study conducted by Reston, Krishnan and Idris (2014) compared the statistics education research in Malaysia and the Philippines. An electronic search was conducted for published research papers on statistics education in 2000-2012, found only nineteen studies have been published in the Philippines. These studies were mostly in the university-level statistics pedagogy, teachers' professional development and academic programs in statistics with the exception of only one study focusing on statistics teaching and learning in the basic education level. The prospect of strengthening statistics education in developing countries as a means of empowering the citizens to address the challenges of globalization (Petocz, 2010) cannot be undermined. Moreover, these research papers published electronically used multiple methodological approaches that focused solely on quantitative research.

Statistical Investigation as an Assessment

The statistical investigation can be used as another form of assessment instead of the usual paper and pencil test (Garfield & Ben-Zvi, 2008). Statistical investigation projects have been employed in statistics research (Halvorsen, 2010; Holmes, 1997; Periasamy, 2006), but only Marriott, Davies and Gibson (2009) highlighted the difficulty in assessing a statistical problem solving. These studies discussed the assessment practices.

Halvorsen (2010) noted that while students learn the process of research, they also learn statistics through the statistical investigation. Students claimed that the project makes the material they study and practice in class much more meaningful. They could see the importance of clarity, simplicity, and discussing research results in answering the research questions. The projects were opportunities to learn outside the context of classroom examinations. Above average students benefitted from the experience, but the focus was on below average students who disliked statistics and mathematics subjects. Nonetheless, below average students not only mastered the subject area, but also enjoyed the activity.

Methodology

This study is an action research that is classroom-based and teacher-driven to show authentic practices using the initial cycle of innovation, research, reflection and recommends further improvement of the approach for the next cycle of practice. The study was conducted in an intact class of forty-four Grade 10 heterogeneous students from a private school in a highly urbanized area in the Philippines with the lead researcher as the teacher implementer. Students' ages range from 15-17 years old. These students belong to the first set of learners of the implementation of the K-12 curriculum in the Philippines. The curriculum integrated statistics as a mandatory area of study in mathematics. Students had already taken data types, data presentation, data collection, simple experiments and outcomes, counting techniques and probability, descriptive statistics such as measures of central tendency, dispersion and variability and position before the conduct of the study. At Grade 10 level, students were expected to be able to produce a statistical mini-research, a requirement set by the Department of Education.

Consent forms were obtained from all students who voluntarily agreed to participate in this study. Fifteen meetings were scheduled with the students. The class was divided into eleven groups with four members each. Every group was expected to produce a mini research for statistical investigation. Students usually do group works at approximately four to six times per subject in a semester.

The instruments used in this study included worksheets, observation field notes, interviews, and reflection sheets. There were four worksheets and each worksheet corresponded to a process of statistical investigation in the GAISE framework.

The meetings were divided according to the GAISE Report Framework's process components (Franklin, et al., 2006). The first phase which is formulating questions consisted of letting students pose questions they plan to answer using statistical measures in achieving the objective or purpose of their mini-research. Since authentic data makes statistical investigation relevant and possibly more enjoyable, the researcher gave students the freedom to choose their own topic. The researcher then checked and assessed the questions before students were given the approval to move on to the next phase – data collection. In the third phase, the data collected were analyzed and interpreted through various statistical methods students deemed appropriate in answering the formulated questions. During the entire statistical investigation, the researcher assisted students who had inquiries. At the last phase, students interpreted the results and wrote their reports. As a culminating activity, each group presented their research study in the class.

By the end of every meeting, each member of the group was asked to answer a reflective questionnaire which focused on their experiences in each phase of the investigation. This practice helped the teacher-researcher understand students' individual skills and the group dynamics in accomplishing each task. Based on these, the researchers considered possible ways to address the challenges and problems encountered by the students.

The students' level of statistical understanding and performance was determined through the indicators of the GAISE framework. To ensure the reliability of the levels of statistical understanding, two senior teachers aside from one of the researchers assessed the levels of the student outputs. The raters first evaluated students' outputs individually per indicator in each process component. Each disagreement was discussed and a consensus was arrived at.

Qualitative data from interviews, observation field notes and student reflections were analyzed using thematic analysis of the six-phase framework by Braun & Clark's (2006, as cited in Maguire & Delahunt, 2017) which was driven by research question. The researchers followed the six phases, not necessarily in linear order: become familiar with the data, generate initial codes, search for themes, review themes, define themes and write-up.

Results and Discussion

Formulating Questions

In this phase of the statistical investigation, students formulated quantitative questions based on their interests. Every time a problem was constructed, the students asked for guidance from the teacher to check whether the questions they formulated were acceptable. Tisel (2015) suggested in his study that in an inquiry activity, the quality of students' research questions develop over time. In this study, most of the students initially formulated questions that were answerable by qualitative data. Examples of formulated questions were "How does being an athlete affect grades?", "How do you improve grades?", and "Do extra-curricular activities affect students' academic performance?" to name a few. In particular, one group raised the question "Does the teacher's performance affect student performance?" The teacher further probed students how data could be obtained to answer this research question. The students responded "We will simply ask students if their teacher affects their performance, by letting students answer a survey. The survey will contain the question: Does your teacher affect your performance in class?" Due to constant revisions and monitoring by the teacher, the students eventually learned to come up with questions that warrant quantitative data. Based on the questions formulated by the students, 26 out of 61 (42.62%) questions were focused on the academic subjects they were taking during that time, 13 questions were about the improvement of the class' general average and 2 out of 61 (3.28%) questions discussed the specialized subjects such as Filipino language for foreigner students and Special Physical Education. The results suggest that majority of the students' interests were limited to academic matters that directly affect them as students.

An example of a research question rated as level B was that of Group 10: "What is the probability of a student getting a cumulative grade point average (CGPA) higher than 85?" They chose this research question because they planned to enter Senior High School and the admission requirement at that time was to get at least 85 in their CGPA.

As can be gleaned from **Table 2**, the students' overall performance in formulating questions was mostly level A except groups 4 and 10, who have reached level B. As regards questions generated out of their interest, all groups achieved Level B in their statistical understanding because they constructed questions on topic of their interest. However, in terms of question distinction, most groups got Level A because they had difficulty foreseeing how their data would look like based on the questions they formulated.

During the investigation, the groups had a hard time constructing quantitative questions due to lack of experience in distinguishing quantitative and qualitative research questions. After much guidance from the teacher in their initial formulated questions, the groups managed to construct their remaining problem statements correctly.

Table 2. Students' Level of Performance in the Formulating Questions Phase

Indicators	Group Number											Total	
	1	2	3	4	5	6	7	8	9	10	11	A	B
Question Distinction	A	B	A	B	A	A	A	A	A	B	A	8	3
Questions of Interest	B	B	B	B	B	B	B	B	B	B	B	0	11
Question Restriction	A	B	A	B	A	A	A	A	A	B	A	8	3
Over- All Performance	A	B	A	B	A	A	A	A	A	B	A	8	3

Another obstacle most groups encountered was the lack of cooperation. Some group members were unable to focus, unproductive and relied heavily from the more able members. Despite these setbacks, the students still gained merits from the activity. One such merit was that despite the struggle in the process, the students learned the difference between qualitative and quantitative research.

Data Collection

Students in this phase decided ways of gathering data to answer the questions they posed in the previous phase of the investigation. Out of 11 groups, four of them (36%) used a survey questionnaire to collect data from their respondents. Five groups, on the other hand, preferred the use of social media and Google forms as means of obtaining data from the respondents. The students chose their classmates as respondents due to convenience and ease as they are readily accessible.

Students' level of statistical understanding in collecting data was Level A in all indicators. This is because students only used a simple census of the class and they performed simple experiments. Most of the students at first were very enthusiastic about the task and begun surveying after receiving approval of formulated questions from the teacher. However, as the investigation progressed, most of the students lost interest due to multiple reasons. One problem most of the groups encountered was the lack of cooperation from their target respondents. Since each one of them is their classmates' target respondent, it took some time to accomplish the surveys. The students experienced difficulty in collecting data because their classmates either forgot or refused to give the data needed. Another challenge encountered were the delay of their group mates in performing the data collection. The students learned in this investigation that when they gather data, they had to make sure that the respondents take the survey seriously. Most of the students discovered that it was tough to force people to give information they were not willing to share. For example, if the survey was about the subject with the lowest grade a student gets, the student just named the subject but not the grade.

Data Analysis

Ample time was given to each group to analyze the collected data to answer their research questions. In this stage, most of the groups divided the task among members instead of doing everything collectively. It was also in this phase where the students needed to recall the uses and application of statistics from their previous grade levels.

This stage was crucial since students had to organize and represent data accurately. All groups used some forms of data presentation such as tables (54.55%), pie charts (45.45%) and Line graphs (27.27%). During the investigation, errors on visual displays of data were manifested in the written outputs. Common mistakes were unlabeled graphs, mislabeled graphs, incomplete and unnecessary graphs. In **Figure 2** for example, to describe students' grades in Social Studies, a frequency table and a pie chart were used. However, notice that there were no table and figure numbers and titles. Moreover, the cumulative frequency in the table is unnecessary and the values in the pie chart do not correspond to those in the table. When asked why they used a pie chart, the students responded saying "We used the Pie Chart because we can easily represent the data at the same time, we can easily make comparisons within the data. It is also the most commonly used chart." This implies that despite reaching Grade 10, some students still had not mastered presenting data and needed proper guidance and orientation about the proper use of visual displays.

SS 1st term Grade Range	F	CF
90-93	5	40
87-89	5	35
84-86	8	30
81-83	13	22
78-80	9	9

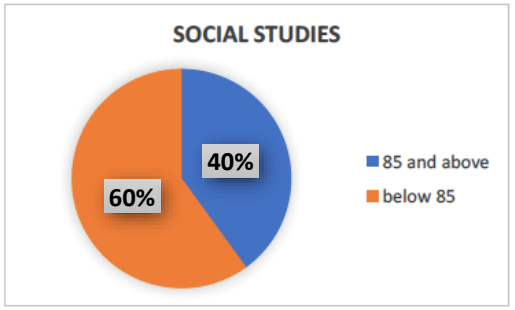

Figure 2. An Example of Students' Work in Presenting Data

Due to various research questions, students used different ways to analyze their data. Measures such as the Mean (81.82%), comparisons (63.64%), and measures of position (27.27%) were present in the data analysis portion of the paper. An example of the comparison was that of comparing the grades of students in the regular and special Filipino classes. Generally, students' statistical analysis comprised mostly of description through charts, and there was no in-depth analysis. Among the measures of variability, only one group used the range as a measure and it was used inappropriately to answer the question "What is the grade range of an average student in the class?". Please see **Table 3** for students' level of statistical understanding and performance in the data analysis phase.

Table 3. Students' Level of Performance in the Analyzing Data Phase

Indicators	Group Number											Total	
	1	2	3	4	5	6	7	8	9	10	11	A	B
Properties of Distribution	A	A	A	A	A	A	B	B	A	A	A	9	2
Variability	A	A	A	B	A	A	A	B	A	A	A	9	2
Comparison of Groups	A	A	A	A	A	A	A	B	A	A	A	10	1
Sampling	A	A	A	A	A	A	A	A	A	A	A	11	0
Association	A	A	A	A	A	A	A	B	A	A	A	10	1
Over- All Performance	A	A	A	A	A	A	A	B	A	A	A	10	1

All groups achieved only Level A in their analysis since they only did analysis at surface level. This finding infers that the students chose to work within their comfort zones. They did not want to explore newfound knowledge and only revolved around the areas they know how to analyze the collected data.

A challenge the groups encountered was the lack of knowledge in using measures in statistics. Most of the groups had a hard time in analyzing the data because they did not know what measure to use and how to use it. Another challenge some groups encountered was the inconsistency of the data supplied by some of their classmates. Aside from this, some students lacked the enthusiasm to participate because they found the activity difficult, leaving the task to the more capable members of the group.

On the other hand, a merit students gained in the investigation was the application of central tendencies. However, since they did all computations manually, they realized that a single mistake could greatly affect the statistic, requiring them to start computing all over again.

Interpreting Results

Students wrote their interpretation of the statistical test results in a report and presented these orally in the class. In the first checking of the students' written report, all eleven groups (100%) summarized the findings, five groups (45%) exhibited variability of the results and showed certainty about their conclusions. This result shows that only five out of eleven groups followed the required content of the written report.

In the overall performance, students' understanding of interpreting results was rated mostly Level A with the exception of Groups 1, 4 and 6.

Students lacked proper technical vocabulary, and had difficulty in explaining and interpreting the statistical test results. The students failed to go beyond reporting the statistics. Instead of interpreting, students focused simply on giving the calculated answers to the research question. The students treated the numerical answers as pure "numbers" that has no attached meaning. When asked what the computed value means, students simply responded with explaining how the value was computed.

Table 4. Students' Level of Performance in the Interpreting Results Phase

Indicators	Group Number											Total	
	1	2	3	4	5	6	7	8	9	10	11	A	B
Looking beyond the Data	B	B	B	B	A	B	A	A	A	A	A	6	5
Generalization	B	B	B	B	A	B	A	A	A	A	A	6	5
Noting Differences	B	A	A	B	A	B	A	A	A	A	A	8	3
Association, Cause and Effect	A	A	A	B	A	B	A	A	A	A	A	9	2
Over- All Performance	B	A	A	B	A	B	A	A	A	A	A	8	3

The tendency of some students to free ride was also seen during the oral report. Some members of Group 11 for example, were asked how they arrived at their conclusions, cannot answer the question despite the detailed description of the statistical investigation processes in their written report. The researcher found out that only one member of the group wrote the written report and the remaining members chose to report the data as their contribution to the group activity. A lot of groups experienced the same challenge where some members were caught unprepared because only one or a few members were fully involved in the statistical investigation.

Despite all these challenges, a lot of merits were also acquired by the students during the statistical investigation process. After much feedback and deliberation from the teacher and two expert panelists, students eventually learned how to interpret the statistical values they computed. The teachers' specific feedback lead to the gradual understanding of the students in statistics as applied in a real-life mini-research. Some students expressed their gratitude for learning the information because they found the knowledge useful for the Science, Technology, Engineering and Mathematics (STEM) strand they would pursue in senior high school.

Consistent with the results of other studies, the use of statistical investigations as the only tool in improving the students' statistical thinking and statistical problem solving strategies proved to be insufficient (Chance, 2002; Wild & Pfannkuch, 1999). Lajoie (1999) found misinterpretations and confusions in the theoretical presentations of the Grade 8 students' statistical projects. Ramirez (2013) on the other hand, discovered that student generated data, especially naïve approaches to data analysis can constrain the development of statistical reasoning and thinking because the quality of the data may be lacking. Zeleke, Lee and Daniels (2006), identified the students' misuse of terminology, inappropriate application of concepts and misinterpretation of results is a deterrent to the development of statistical thinking and reasoning.

Conclusion

The GAISE framework serves as an excellent guide for teachers on how to aid students in conducting a statistical investigation. Through the use of the GAISE framework, the teacher researcher was able to assess students' understanding of statistics as they underwent statistical investigation and found that there exists a gap between students' learning of statistics in the classroom as a subject and its application to the real world in the form of a mini-research and problem solving. As seen in the results of this study, students' statistical understanding and performance during the statistical investigation were mostly of the lowest level A and very few among them reached the average level B.

Students can correctly compute a statistic but did not know among which test statistic was applicable and appropriate to answer a particular research question. This implies that students needed more exposure and experience in real life application of statistics. Moreover, the teacher researcher must take into consideration the complexity of the task, the acquired knowledge and other factors affecting the investigation of the students. These in part either support or hinder the students' development of statistical understanding. The teacher noted that careful consideration of the students' activities in each phase of the statistical investigation is very important. For example, in formulating questions, some groups had a hard time starting the investigation due to lack of knowledge or distinction between questions that elicit quantitative and qualitative data. A learning package to teach students on how to do statistical investigation could include more concrete examples to illustrate the distinction between these two types of questions in the formulating questions stage.

There was also the perennial problem of some members of the group who were not contributing to the task at hand – question formulation, data collection and data analysis, during group work and presentation. To address this, cooperative learning technique can be incorporated in group works to ensure more students, if not all, will be actively involved. Nonetheless, the use of statistical investigation in mini-research and real-life applications provided students opportunities to enhance their social skills so they can work effectively with people in future workplace.

This study was conducted in a single class of forty-four Grade 10 students in the newly implemented curriculum. The curriculum is limited to descriptive statistics, this is why students' investigations were limited. The conclusions were based on the outputs presented by the students during the course of investigation and since the sample is small, it does not generalize the findings to the greater population.

The levels of statistical understanding of the students were only assessed during the investigation. For generalization purposes, researchers may consider increasing the sample size. It is also interesting to see if students' levels of statistical understanding differ before and after statistical investigation.

Professional Reflection of the Researchers

The Role of the Teacher

This study has shown the importance of teacher's guidance, monitoring and feedback in each phase of the statistical investigation process.

Aside from diligently providing specific feedback, the teacher also learned to pay close attention and supervision over students because some groups have a tendency to lose focus in the middle of the task.

Formulating Questions

The lack of input during the investigation in this cycle hindered the development of the statistical understanding of the students. At times, the teacher was tempted to phrase the question for the students since this is easier than asking students the right guiding or probing question that can lead them to formulate the right research questions. This could have been avoided if enough examples of questions were given so students could be wary if their formulated question elicits quantitative or qualitative data for statistical treatment.

In this study, the students were given free rein to choose their questions. This challenged students to develop their problem posing skills. However, some considerations need to be made so students can be successful in this phase of statistical investigation. The teacher may consider the competencies tackled by the students so far and limit the possible topics of interest that the students may research on, this is to ensure that the skills learned is applied.

Albeit up to what extent can the investigation be student-designed or teacher designed? An investigation that is student-designed gives students a choice of what specific topics of research they are interested in. When students are given a choice, the more motivated they will pursue answering the research out of curiosity and the greater the chance of attaining a successful investigation. A teacher-designed statistical investigation however stays true to the purpose and follow prescribed competencies.

Collecting Data

Collecting data as an activity also develops students' skills in interacting with other people. In this study, the turn-out of data were not as expected, students needed to follow up their respondents. They learned to respect their respondents' privacy if they chose not to divulge some information such as their grades.

The researcher also recommends letting students experience managing data on their own for as long as they are closely being monitored to maintain their focus especially if the data they collect correctly answers the research questions posed and attains the objective.

Analyzing and Interpreting Data

In this study, the students analyzed and interpreted the data collected on their own. However, the students' naïve treatment to data resulted in a shallow interpretation and analysis of the study. The scaffolding of the teacher was not enough in addressing the needs of the students during the data analysis. The researcher notes that in the next cycle, checking students' prior knowledge in statistics can identify the weaknesses and strengths of the students so that appropriate interventions could be done before the conduct of statistical investigation. A short discussion on the statistical concepts taken in previous grade levels could be useful during the statistical investigation. This is to assist students in recalling what test statistics are available and how to appropriately apply these in their statistical investigation.

The merits gained from the experience of statistical investigation outweigh the challenges and struggles in the process. Students learned how statistical research problems are phrased, time management in data collection, use of technology in data collection, respect for data privacy, work ethics in achieving a common goal, among others.

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