Experiences Students Should Have in Learning Statistics and What Teachers Need in Order to Provide Such Experiences

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The current challenge in K-12 mathematics education is to ensure that students as future citizens obtain practical quantitative skills necessary to successfully travel the path of their future studies, careers, and personal life.

Quantitative literacy "empowers people by giving them tools to think for themselves, to ask intelligent questions of experts, and to confront authority confidently (p. 3)," according to *Mathematics and Democracy: The Case for Quantitative Literacy* (Steen, 2001) as cited in *Guidelines for Assessment and Instruction in Statistics Education* (GAISE) *Report* (2007).

The GAISE Report recommends

> ...students formulate questions that can be answered using data and address what is involved in wisely gathering and using that data. Students should learn how to collect data, organize their own or others' data, and display the data in graphs and charts that will be useful in answering their questions. This standard also includes learning methods for analyzing data and ways of making inferences and drawing conclusions from data. The basic concepts and applications of probability also are addressed, with an emphasis on the way probability and statistics are related (p. 5).

To ensure that statistics taught in the classroom is focused on developing these abilities, and is not limited to the teaching of concepts and calculations without meaning, we must ensure that teachers have the opportunity to develop those skills themselves.

This brief presents guidelines for the learning experiences teachers and students should have. Suggested experiences are focused on building meaning for understanding statistical concepts and not simply using procedures.

The organization of this document follows the components included in the process of using statistical investigations in problem solving situations as stated in GAISE (2007). These four components are: formulate questions, collect data, analyze data, and interpret results.

I. Formulate Questions

This component involves clarifying the problem of interest and formulating one or more questions that can be answered with data.

Teachers should be able to design activities that motivate the students to investigate a problem that is of interest to them.

Initial activity: Students construct their own questions.

Teachers can ask the class to think of something that can be put into a table or graph to share with the whole class. For example, ask the students questions such as:

- What would you like to know about your classmates?
- What would be interesting to find out about the students/teachers/staff in our school?
- What problems or issues do we have in our class/school/community and what data would be necessary to have/obtain to understand them?
- What conclusions are possible to draw or what inferences can be made for your question? (hypothesis)

Teachers and students should consider the context (classroom, school, community, country, etc.) of the questions and the possibility of actually finding an answer to those questions.

Follow up activity: Analyze existing questions,

Teachers should encourage students to study existing questions or problems and the kind of data that have been collected in order to tackle them. When looking at those questions/problems students can determine what is of concern or interest to a community or country and investigate the kind of questions that can be addressed using quantitative data.

Together teachers and students should analyze the possibility of investigating those questions or collecting data with the resources available to them.

II. Collect Data

This component involves designing a plan to collect appropriate data to answer the question and using this plan to collect the data.

Teachers should focus on helping students to identify what data are necessary to tackle the selected issue and making a viable execution plan to collect the data.

Initial activity: Teachers should engage students in a discussion of how to take a problem and design a plan that includes enough information to know how to collect the data. Some questions that can be used to lead this discussion are:

- What is the group of individuals or units that form the population?
- What to collect?
- Will this data help answer the question?

- Who is going to provide the data? (a person, a measure, a document, an observation)
- How to collect the data? (a simple question, a survey, a measuring tool, an online tool)
- Where to collect the data? (in the classroom, at school, in the city/town, in printed documents, online)
- What are the variables? What kind of variables are they? (quantitative - qualitative, discrete - continuous)
- Can the problem be solved by studying a sample instead of the whole population? If so, what kind of sample? How can the sample be selected?

After students discuss these issues, it is time to write a plan and define the strategies to carry it out. Be sure that the plan is something that the students can really do, can be done in the available time, and helps to reach the goals of the class.

Teachers may want to share with students the kinds of instruments that can be used to gather the data and the best way to use them.

Follow up activity: Put the plan into action.

Discuss with students the importance of considering the conditions under which data should be collected: time, space, cultural conditions, etc. and what can happen if attention is not given to these conditions.

III. Analyze Data

This component calls for the selection of appropriate graphical and numerical methods to summarize the data and to use these methods to analyze the data.

Students should discuss the characteristics of various possible graphical and numerical methods of representing and analyzing data, and which would be more appropriate in the particular case.

Initial activity: Students select methods to organize and present data.

Students should select the kind of graph, table, or representation that best fits the collected data. Some leading questions can be:

- What types of data can be represented in each type of graph?
- What advantages or disadvantages does each kind of representation have?
- How should we organize the data? Simple frequencies, percentages, intervals, pictographs, etc.?
- What software can be used to organize the data? Does using technology make the analysis easier?
- What information can be obtained from the chosen representations?

Follow up activity: Use the selected methods to represent and analyze the data. Students create graphs and make calculations. Special attention should be placed on the components of each kind of representation, such as labels, titles, units, etc.

Depending on the level of the group, calculations may include: totals per item, percentages, mean, median, mode, measures of dispersion, correlation coefficients, least squares regression line, etc. In the same manner the graphical representations may include: pictographs, bar graphs, pie charts, histograms, box plots, scatter plots, etc.

IV. Interpret Results

This component involves interpreting the analysis and relating the interpretation to the original question/issue.

During data analysis students should be guided to extract information from the data pertinent to the problem/issue in question, distinguish between results that are pertinent and those that are not, and limit their conclusions to the information obtained without adding subjective statements. Based on the information obtained from the study, students should come up with conclusions that address the original question/problem.

Initial activity: Students write down conclusions.

Students should go beyond data analysis and try to draw conclusions from their work, for example what is the meaning of the percentages, what does the standard deviation represent, what information can I get from a chart? Teachers can use the next questions to guide discussion:

- What information can we get about the distribution of values related to the problem?
- What can we say about the frequencies? Who has more? Who has less? By what amount?
- How can our tables, graphs and calculations help us to better know and answer the initial problem?
- What are the tendencies in the data collected? (variability, shape and center of the distribution)
- What can be inferred about the sample/population?
- What relationships do we find in the graphs?
- Is there any correlation between the variables? What is the existing relationship between the variables?

Follow up activity: Revisit the original problem/question.

At this point students should be able to return to the original question and to analyze whether the given conclusions answer the question or if it is necessary to do other calculations or if the data are not adequate to make a conclusion.

Teachers should be aware and help the students understand some inferences cannot be made from samples that are not representative of the population.

Depending on the level of the students the interpretations may be as simple as just a summary of the results obtained or as complex as making inferences, calculating probabilities, and making predictions.

Experiences for teachers

In this section we want to provide an insight into how the experiences presented above can be carried out with teachers in a professional development setting.

In general, we strongly suggest that teachers should be exposed to the same experiences proposed for the students with some discussions related to how to teach interposed with the activities for each component. This will be a time for reflection and sharing. In the next paragraphs we highlight some issues that teachers should take into account for each of the components.

Formulate questions: after formulating different questions, we expect teachers to engage in a discussion about the kind of problems or questions that can be used depending on students' grade level, context, tools. Teachers should come up with some examples for each level. Teachers might also experience some question that cannot be answered using statistical methods so they can build arguments they can use when working with students.

When posing questions, special attention needs to be placed on issues related to equity, social trends, sensitive topics, etc.

Collect data: This is a good time to introduce statistical concepts: sampling, population, variables, type of variables, and instruments to collect data, among others. Teachers can go further in promoting the use of different resources available to collect data or use existing data. Depending on grade level teachers should think about designing and using a variety of instruments and ways to collect data.

Issues related to the use of samples and populations, and what is necessary for any inference to be made should be discussed before the decisions on how the data will be collected are made.

Analyze data: Teachers should experience using all possible methods to analyze a problem and then think through all those methods looking for advantages and disadvantages, correspondence to grade level curriculum and the combinations of methods that will provide a better sense of what is going on with the sample/population.

For large data sets, technology can be required. We suggest to use the most common resources available for teachers at their own schools and to develop a laboratory to show how these resources can be used with students to organize and analyze data.

Interpret results: Be aware that going back to the question/problem is required in all components although it is emphasized in this one. We want teachers and students to go beyond representing data and making calculations and to think about the decisions that can be made based on the results of a statistical analysis of the data. Teachers should lead discussion to look for patterns, to describe the behavior of a sample/population, predict phenomena, calculate the probability that something will happen, look for consequences if decisions are made that are not based on the statistical analysis.

Finally, we want to focus on the original question/problem and to provide enough data to really understand and tackle it.

Assessment (formative and summative) should be present in all components of the process to assure the success of the investigation. Teachers may want to design rubrics to evaluate student progress and to define what the focus of the evaluations should be.

As a closing activity for a teacher development, teachers can write an activity that they can use with their own students and if possible share the results with their colleagues later on as a teacher study group.

References

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