DEVELOPMENT STATISTICAL THINKING IN FUTURE MEXICAN TELESECUNDARIA TEACHERS

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The objective of this research is to analyze qualitatively the implementation of statistical projects as a strategy for developing statistical thinking in future telesecundaria teachers. This research provides valuable elements for the teacher training process such as having theoretical and methodological aspects that guide the training of prospective teachers. The theoretical elements—a framework of indicators and criteria to analyze the development of statistical thinking—serve as reference points around which to direct teacher learning; the methodological aspects favor the context to interact with these theoretical elements and take part in them. The results indicate that projects allow future teachers to develop important elements of statistical thinking and appreciate the use of statistics as a tool for solving problems such as those they face during their profession.

INTRODUCTION

The importance of analyzing teacher training processes for teaching statistics has been recognized by various institutions such as the International Commission on Mathematical Instruction, the American Statistical Association, and the International Association for Statistical Education (Santana, 2020). There is research that has analyzed the use of projects for teacher education (Batanero & Díaz, 2011; MacGillivray & Pereira-Mendoza, 2011). Some studies focus on aspects of the use of projects in relation to the development of statistical thinking (e.g., Inzunza, 2017). Research that has analyzed the use of projects as part of teacher training focuses its attention on showing the experiences of these future teachers when working with projects (Vithal, 2002), on the impact that projects can have for the learning of statistics curricular content (Godino et al., 2013), and as a mechanism to promote research among teachers in training (Mendes, 2006). In addition, these investigations show the mistakes that future teachers tend to make during the process of working with projects (Batanero & Díaz, 2011). Collectively, these investigations suggest that to achieve good training in statistics, future teachers should participate in the projects as if they were their own students, because this can help them to understand the pedagogy that underlies project work (Mendes, 2006) and to understand how statistical concepts can be taught through contextualized problems (Rivas et al., 2019).

In this paper, we report the elements of statistical thinking that were developed by the future telesecundaria teachers during their participation in the activities of a statistical project. The telesecundaria pedagogical model consists of a 15-minute television program with the subject and lesson corresponding with the curriculum. This is followed by 35 minutes of class work, guided by only one teacher per group, using activities proposed both in the textbooks and in the didactic planning.

FRAMEWORK

This study poses the following question: what elements of statistical thinking are promoted by the implementation of a statistical project for future telesecundaria school teachers' learning? To answer this question, a series of criteria, elements, and indicators (Table 1) of statistical thinking development during the projects are used, which are based on the statistical thinking model of Wild and Pfannkuch (1999). (See Table 1 for the elements and indicators.)

For each of the elements that make up statistical thinking, a set of specific criteria were designed to represent the demands of the model's indicators. Because the 23 indicators are general descriptors, 57 specific criteria were developed to provide more detail on the indicators (See Table 2 for the criteria associated with the second element, Types fundamental to statistical thinking; also see Santana, 2020).

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Table 1. Framework of elements and indicators

Elements	Indicators
1. The investigative cycle	1.1. Problem
	1.2. Plan
	1.3. Data
	1.4. Analysis
	1.5. Conclusions
2. Types fundamental to statistical thinking	2.1. Recognition of need for data
	2.2. Transnumeration
	2.3. Variability
	2.4. Reasoning with statistical models
	2.5. Integrating the statistical and contextual
3. The interrogative cycle	3.1. Generate
	3.2. Seek
	3.3. Interpret
	3.4. Criticise
	3.5. Judge
4. Dispositions	4.1. Scepticism
	4.2 Imagination
	4.3. Curiosity and awareness
	4.4. Openness
	4.5. Seek deeper meaning
	4.6. Being logical
	4.7. Engagement
	4.8. Perseverance

METHOD

The approach of the study is qualitative because it is based on the participation of the future teachers and their way of understanding the learning elements involved in working with statistical projects, as well as their experience in this type of methodology. The population of interest for the objectives of this research was formed by the students of the Escuela Normal Rural "Carmen Serdán" (ENRCS). This school is a teacher training institution located in the municipality of Teteles de Ávila Castillo, in the state of Puebla, Mexico. The participants of this research were 17 second grade students of the bachelor's degree in Telesecundaria Education (LESET) who were in their fourth semester taking the subject 'The Teaching of Mathematics II' (EM-II) during the 2018–2019 school year. The average age of the students was 19 years old. The Telesecundaria pedagogical model consists of a 15-minute television program with the lesson and subject corresponding to the curriculum, followed by 35 minutes of class work, guided by the teacher, and activities proposed both in the textbooks and in the didactic planning.

The curricular design of the EM-II course consists of a total of three units: the first unit is dedicated to analyzing problem solving and the role of the teacher in the learning of mathematics; the second unit is dedicated to reviewing didactic suggestions in the treatment of some curricular content; and the third unit is aimed at reflecting on teaching processes and didactic resources in the telesecundaria school. The EM-II course covered 20 sessions of 90 minutes each. Of the 20 sessions, 15 were devoted to the development of the statistics project (SP), which was organized in five phases: (a) Statement of the research problem, (b) Planning the development of the project, (c) Execution of project activities, (d) Analysis of the data collected in the project, and (e) Presentation of project results. Each phase lasted three sessions. Because the project was intended to be the central instructional strategy of the EM-II course, it was thought necessary that all activities and products associated with the project would comprise teachers' final evaluation, that is, the evaluation that the future teachers obtained in the project would be the final evaluation that they would obtain in the course.

Table 2. Framework of criteria for types fundamental to statistical thinking

2. Types fundamental to statistical thinking	
2.2.1	*Recognition of the need for data*
2.2.1a	Activities are promoted to understand that data are required in order to make judgments about a problem or situation.
2.2.1b	Activities are promoted in which there is a need to collect real data rather than to use anecdotal data or personal experiences to solve a problem or make a judgment about a problem or situation.
2.2.1c	Emphasis is placed on the use of data with the goal of answering statistical questions.
2.2.2	*Transnumeration*
2.2.2a	Activities are encouraged to transform raw data into graphical representations, statistical summaries, etc.
2.2.2b	Activities are encouraged to use different data representations (tables and graphs) according to the characteristics of data.
2.2.2c	Activities are encouraged that involve transforming or re-expressing data in ways that reveal new characteristics about the data.
2.2.3	*Variability*
2.2.3a	Activities are encouraged to model variation for prediction, explanation, or control.
2.2.3b	Look for variability by finding patterns and relationships among variables.
2.2.3c	Promote activities to understand that there are many sources of variation.
2.2.3d	Promote activities to look for possible explanations for variability in the data.
2.2.4	*Reasoning with statistical models.*
2.2.4a	Activities are encouraged to reason about a data set as a group rather than reasoning about individual cases.
2.2.4b	Activities are encouraged that allow the use of statistical models (e.g., graphs, measures of center, measures of dispersion, confidence intervals, p-values, regression models, or time-series models) to represent and think about the phenomenon under study.
2.2.5	*Integration of statistics with the context*
2.2.5a	Conclude a statistical problem by interpreting the statistical results in terms of the context of the problem.
2.2.5b	Promotes the use of knowledge of the context in the interpretation of different statistical results (e.g., result of a mean, standard deviation, etc.).

The data were obtained through video recordings of the class sessions dedicated to the project. The analysis consisted of a classification of the data according to the five phases in which the SP was developed. The classification led to the thematization of the discourse—transcripts of all the class sessions—in which the discourse is analyzed using the framework of indicators for how the future teachers developed characteristics of statistical thinking through project work. Thus, the framework served as a reference for the analysis of the data, which was carried out based on the indicators and criteria designed according to the theoretical ideas of statistical thinking. After the codification of elements, criteria, and indicators, those evidences were chosen that were most similar to the criteria established as a basis for detecting the development of statistical thinking.

RESULTS

The four elements of statistical thinking (see Table 1) were developed by the future telesecundaria teachers in carrying out the statistical project. Some ideas that illustrate how they were developed are presented below; however, for reasons of space, only a general description of the elements of statistical thinking shown by the prospective teachers in carrying out the project activities is given. In this section, some transcripts of what are considered evidence of statistical thinking development have been placed in quotation marks; in each of the four elements of statistical thinking, the identification numbers for the indicators belonging to each element that was developed have been placed in square brackets.

Elements of the Investigative Cycle

[1.1] Each of the trainee teachers wrote at least one statistical question (e.g., one future teacher asked, "did the implementation of the didactic proposal improve students' ability to solve direct proportionality problems?") to which answers were sought through the collection of varying data. [1.2] Planning was experienced by making certain decisions that involved both knowledge of the context and statistical content. In the case of contextual knowledge, the students anticipated issues related to the locality, school, and group where the practice would take place because this could impact data collection. In terms of statistical content knowledge, the plan phase involved the exposition of ideas related to what needed to be measured—the scores—and how to measure it—through the design and application of written tests, whether a sample was required, the type of study to be conducted (i.e., quasi-experimental study). [1.3] During the class sessions, the students reflected and communicated ideas on how to deal with problems that might arise in data collection (e.g., the group's teacher not allowing the written tests to be administered to their group). To collect their data, the prospective teachers had to design an instrument that would allow them to obtain useful numerical information to answer the questions. The instrument was a standardized written test with multiple-choice answers. [1.4] Analysis was a phase that involved the application of different statistical concepts and ideas such as tables, graphs, summary statistics, hypothesis testing, and effect sizes. The idea of variability of the data was considered through the interpretation of the variance and standard deviation for results; as well as with the use of statistical graphs to make group comparisons with which they could visualize the variability present. [1.5] The conclusion phase was carried out by means of written reports and oral presentations summarized in posters prepared by the future teachers, and conclusions were drawn about the problem investigated. In their conclusions, teachers tried to integrate the results obtained in the hypothesis tests, the effect size, and the context of the telesecundaria schools in which the teaching practices had been carried out.

Elements of the Fundamental Types for Statistical Thinking

[2.1] The prospective teachers understood that it was not possible to solve their statistical problem or answer their questions without having data obtained from the context from which they were generated (e.g., one student commented that "a statistical question is one that can be answered by collecting data and where it is known that there will be variability in those data"). [2.2] After the prospective teachers collected their data, they proceeded to capture it and then did various transformations that encompassed a simple frequency table, a summary of descriptive statistics, statistical dot plots, box plots, histogram, two statistical hypothesis tests—paired *t*-test and Wilcoxon, and the effect size test. The use of Minitab and SPSS statistical software facilitated the process of transnumeration performed by the future teachers. [2.3] To illustrate variability, teachers were presented with an example on electoral surveys, which was used to address something related to variability (e.g., a student responded that "in the results of a survey, variation must be considered because not all people will have the same electoral preference and therefore their answers will be different"). [2.4] Reasoning with statistical models was promoted to the extent that the future telesecundaria teachers showed the use they made of various statistical models (e.g., parametric hypothesis testing) that allowed them to address their statistical problem. [2.5] The prospective teachers had to write interpretations of their statistical results based on the school context in which the teaching practice took place (e.g., determining the impact of their didactic proposal).

Elements of the Interrogative Cycle

[3.1] During the activity planning phase for the statistics project, the prospective teachers had to socialize their knowledge and generate ideas about the characteristics to consider for the study design (e.g., future teachers asked questions such as "what is a quasi-experimental design?"). [3.2] During the project sessions, the students conducted an internal search when they socialized some ideas about the options that could be considered to solve possible difficulties in collecting the data (e.g., non-attendance of the teacher in charge of the practice group). [3.3] The future teachers discussed and analyzed the class sessions on ideas related to the design of the project. They began to identify in their vocabulary the concept of quasi-experimental design which was totally unknown to them. On the other hand, the future teachers had to interpret the feasibility of the statistical tools they should consider for their project. [3.4] This element was developed because the future teachers had the feasibility of using certain

statistical tools used for the analysis of the project and some ideas about the design of the study they had to carry out (e.g., reflecting on whether the use of a certain statistical model was correct, or thinking about whether the conclusions made sense).

Elements of Dispositions

[4.3] In terms of curiosity and awareness, the use of statistical software was one of the activities that most aroused curiosity in the future teachers, because in no other subject in the LESET curriculum had they been required to use computer applications for specific purposes. But this curiosity was accompanied by the awareness that they had to find out how to use the software for the purposes of their projects (e.g., one student commented that "in Excel you need to know some formulas and that seemed a bit complicated, so I preferred to use Minitab for this summary of descriptive statistics"). [4.5] The search for deeper meanings was a fundamental indicator during the projects, and the students evidenced this search because they had to investigate documentary sources related to statistical concepts that they presented orally in front of the class. This search was evident because in their reports they included definitions for many of the statistical tools used (e.g., variance, kurtosis, skewness, etc.) without being explicitly requested by the trainer. [4.7] Engagement was developed because there was an inertia in the group work dynamics; none of the students wanted to be left behind in the activities. But the commitment went beyond the course, because in the last session, some students expressed their intention to continue exploring more of this project methodology with their own groups. [4.8] Perseverance could be seen in the extent to which the students had the determination to remain constant in the development of every one of the activities necessary to conclude their projects.

CONCLUSIONS AND IMPLICATIONS

The context in which the research was carried out is relevant for the training of basic education teachers in Mexico. In fact, teacher training colleges are an ideal place to develop research on the training and updating of teachers. During this training process, the teacher training students were able to learn and apply a greater number of topics in statistics and mathematics and to use technological tools for data analysis. The statistics project covered not only statistical content, but also mathematical content that is studied at the secondary level because the future teachers addressed didactic proposals of mathematical topics on geometry, algebra, arithmetic, probability and statistics, and trigonometry. The design of the didactic proposal also implied developing the necessary didactic skills to address these topics.

The statistics project also favored a knowledge of project work; knowledge demanded by the current curricula because this type of work is a strategy that is recurrently mentioned in the curricula, both in secondary education and in teacher training. In addition, from the implementation of the project, the teachers in training had an important approach with the statistical thinking model (Wild & Pfannkuch, 1999), which allowed them to give meaning to one of the suggestions mentioned in the mathematics curriculum for secondary education: to develop statistical thinking in their own students (Secretaría de Educación Pública, 2017).

The statistics project was used as a central instructional strategy from which the curricular contents of the EM-II subject itself (e.g., design of mathematics didactic proposals) and the development of competencies from other subjects (e.g., writing texts in Spanish and English) were addressed. It is important to mention that the challenges faced in the research also involved technological issues, for example, limitations in the connectivity and access to the internet that the student teachers had. Although, in theory, the ENRCS provides internet access to the students, in reality this does not happen because the infrastructure is very limited, and the connection services are not adequate. Within the ENRCS facilities, not all students have access to the internet and, if they do, it is with a very slow browsing speed. Due to the fact that the statistics project implied that the students were constantly accessing the Moodle platform, and because of the aforementioned problems, many of them had to invest in buying internet packages to access through their (very basic) smartphones or in going to a cybercafe and paying to be able to access the internet.

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