EXAMINING VENEZUELAN SECONDARY SCHOOL MATHEMATICS TEACHERS' PROFESSIONAL COMPETENCIES TO TEACH STATISTICS: FOCUSING ON THE INSTRUCTION OF DESCRIPTIVE STATISTICS

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This article reports on a study of mathematics teachers' professional competencies for teaching statistics at secondary school, which are of critical importance to achieve the aims of the mathematics curriculum regarding statistics education. In this study, such competencies are defined using an eight-dimensional construct, comprised of the six aspects of professional knowledge identified by Ball, Thames and Phelps (2008), as well as conceptions of variability and beliefs about statistics teaching and learning. Based on this framework, a survey instrument was designed and administered to fifty-three secondary school mathematics teachers working at the metropolitan area of Caracas, Venezuela. The collected data not only revealed strengths, weaknesses and misconceptions in participants' professional knowledge base, but also led to a deeper understanding about how the identified dimensions of professional competencies for teaching contents in the field of descriptive statistics might affect each other. Furthermore, some other interesting findings, trends and implications yielded from the data analysis are discussed.

INTRODUCTION

Statistical literacy is key to intelligently participate in many fields of today's knowledge-based society (Shaughnessy, 2007). Aiming at statistical literacy, recent curricular reforms in many countries—including Venezuela—have brought into the secondary school mathematics curriculum topics related to statistics (e.g., NCTM, 2000; ME, 1987; CENAMEC, 1991). For students, the exposure to statistics in secondary school plays a critical role in the development of their knowledge base, attitudes and beliefs about the discipline. Firstly, because for many of them such exposure might be the last and only statistics formal program they will ever take. Secondly, because for those students proceeding to tertiary education, such exposure would prepare them for statistics in higher education. Therefore, secondary school mathematics teachers play a highly important role in promoting statistical literacy in their students, and such a role demands from them specific professional competencies, without which the aims of the mathematics curriculum regarding statistics education cannot be achieved.

Despite the important role played by secondary school mathematics teachers in fostering statistical literacy among future users of statistics, very little has been reported in the literature regarding their professional competencies—i.e., professional knowledge and affective-motivational traits (Döhrmann, Kaiser & Blömeke, 2012)—to teach fundamental statistical ideas, particularly those in the area of descriptive statistics, which, in the case of Venezuela, represent about three-quarters of the total number of statistical topics found in the current secondary school mathematics curriculum (ME, 1987; CENAMEC, 1991; Salcedo, 2006).

Given the state of affairs outlined above, the present study attempts to make a contribution to the literature of statistics education by addressing the aforementioned gaps in research. Firstly, the literature on both teacher competence and statistics education is reviewed, in order to identify elements of professional competencies to efficiently teach statistical ideas, as well as to propose a conceptualization of teachers' competencies to teach statistics at secondary school. Secondly, on the basis of such conceptualization, a survey questionnaire is developed and implemented, in order to qualitatively examine and describe the professional competencies that Venezuelan secondary school mathematics teachers have to teach notions of descriptive statistics.

CONCEPTUALIZING PROFESSIONAL COMPETENCIES TO TEACH STATISTICS

After an examination of the research on teacher competence and statistics education, eight elements were identified and selected for the framework proposed by this study (cf. Figure 1). These elements were categorized into professional knowledge and affective-motivational domains. The domain of professional knowledge—which will be regarded here as *statistical knowledge for*

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teaching (SKT)—is comprised of the constructs *subject matter knowledge* (SMK) and *pedagogical content knowledge* (PCK), each of them structured in a tripartite form, according to Ball et al. (2008). The affective-motivational domain is comprised of conceptions of variability as well as beliefs about statistics teaching and learning (Shaughnessy, 2007; Eichler, 2011; Isoda & González, 2012; González, 2012, 2013). Each one of these elements has been reported in the literature as factors influencing every aspect of teaching.

In the present study, in order to meet the case of teaching statistics, the cognitive trait *common content knowledge* (CCK, Ball et al., 2008, p.399) will be regarded as statistical literacy, since the knowledge and skills related to the latter are used in settings other than teaching, analogously to the case of CCK. The research efforts of Isoda and González (2012) and González (2013) provide empirical evidence that teachers' conceptions of variability can be made explicit by answering tasks in which knowledge and understanding of variability-related ideas are required. This establishes a connection between conceptions of variability and statistical literacy, or CCK here. The research carried out by Eichler (2011) provides empirical evidence that teachers' beliefs can be distinguished from examining the features of the lessons planned by teachers—which establishes a connection with the cognitive trait *knowledge of content and teaching* (KCT) (Ball et al., 2008, pp.401-402). With these facts in mind, a framework conceptualizing mathematics teachers' professional competencies to teach statistics was developed (cf. Figure 1).

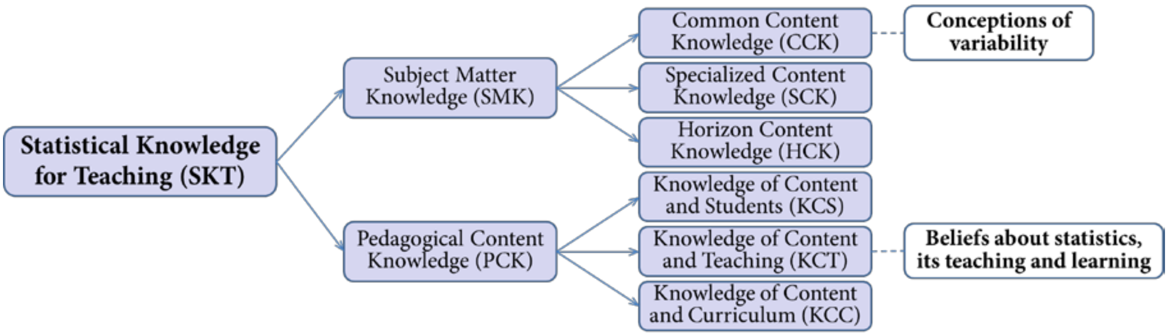


Figure 1. Proposed conceptualization of teachers' professional competencies to teach statistics

Through the combination of extensive literature review and consultation with experts in the field, twelve indicators were identified as potential predictors for the presence of each one of the six elements comprising the cognitive domain in the proposed framework, in order to provide a comprehensive assessment for SKT (cf. González, 2012; 2013).

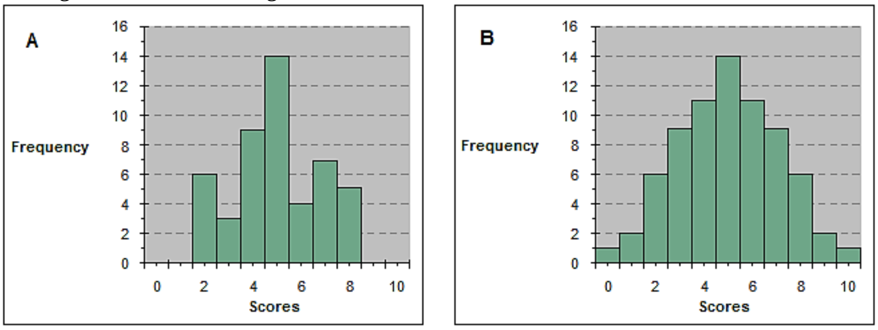
SURVEY DEVELOPMENT AND IMPLEMENTATION

Based on the Venezuelan secondary school mathematics curriculum, as well as on the eight elements of professional competencies for teaching statistics and the twelve indicators of SKT identified by this study, a pen-and-paper instrument was developed. After piloting and refinement, the instrument was administered between July and September 2012 to a purposive sample of 60 secondary school mathematics teachers working in the metropolitan area of Caracas, Venezuela. From these teachers, 53—19 working only at lower high school, 15 only at upper high school, and 19 at both levels—decided to participate in the study. The instrument, designed to be completed in one hour, is comprised of seven questions about a statistical task, aiming to elicit all the eight elements of teachers' professional competencies to teach statistics previously identified (to see all the questions, cf. González, 2012, 2013). The task—originally developed by Garfield, delMas & Chance, 1999—addresses many variability-related ideas in the field of descriptive statistics, through the comparison of the histograms of two distributions. In this study, the original task was slightly modified, in order to facilitate the calculations that could be made by respondents. Due to space limitations, the discussion in this article will be limited to the results obtained in Question (a) (cf. Figure 2), which aims to elicit indicators of CCK as well as conceptions of variability.

ITEM 1

Please, read carefully the following task and answer the questions below:

Look at the histograms of the following two distributions:



Which distribution (A or B) do you think has more variability? Briefly describe why you think this.

(a) Answer this task in as many different ways as you can. Please, be sure to show every step of your solution process.

Figure 2. Task and Question (a) used in the present study

Table 1. Results obtained from participants' answers to Question (a) – Frequency and percentage

Category	Frequency (%)			
	Lower High School (19 teachers)	Upper High School (15 teachers)	Both Levels (19 teachers)	Total (53 teachers)
A0: No response.	2 (10.5)	2 (13.2)	1 (5.3)	5 (9.4)
A1: Distribution A, giving no reason, by arguing intuitive ideas, or based on a mistaken calculation.	1 (5.3)	1 (6.7)	1 (5.3)	3 (5.7)
A2: Distribution A, based on a misinterpretation related to symmetry and/or a poor fit to a normal distribution.	1 (5.3)	1 (6.7)	3 (15.8)	5 (9.4)
A3: Distribution A, based on arguments related to differences in the heights of the bars (e.g., "Distribution A because is bumpier").	3 (15.8)	1 (6.7)	5 (26.3)	9 (17.0)
A4: Distribution B, giving no reason, by arguing intuitive ideas, or by misinterpretation (e.g., "B has a larger span in frequency than A").	4 (21.1)	1 (6.7)	4 (21.0)	9 (17.0)
A5: Distribution B, based on arguments related to simple recognition of variability (i.e., answers concerned only with extremes or ranges of each distribution; e.g., "because it's more spread out").	2 (10.5)	1 (6.7)	2 (10.5)	5 (9.4)
A6: Distribution B, based on arguments related to sophisticated recognition of variability (i.e., answers connecting both middles and extremes; e.g. "because the scores differ more from the center").	6 (31.5)	8 (53.3)	3 (15.8)	17 (32.1)

RESULTS

Forty-eight teachers—17 working at lower high school, 13 at upper high school, and 18 at both levels—answered Question (a). A "bottom up" approach to coding was undertaken to analyze the collected data, from which six distinctive categories emerged. Table 1 indicates all the identified categories, as well as the number of teachers' answers to Question (a) falling into each one of them.

DISCUSSION

Only 41.5% of the surveyed teachers (22/53) gave an appropriate response to the posed task. Among the 17 teachers who gave answers falling into category A6, 9 (17.0% overall) created frequency distribution tables to calculate measures of variation, while 9 (17.0% overall) supported their answer with a naked-eye description and interpretation of the data clustering around the mean.

Almost a third of the surveyed teachers (17/53) argued incorrectly that Distribution A is the one with more variability. This group of teachers showed evidence of harboring misconceptions commonly exhibited by mathematics students at secondary and tertiary education. For example, teachers in category A2—9.4% (5/53) of the surveyed teachers in the present study—showed evidence of mistakenly thinking of variability in terms of symmetry or degree of fit to a normal distribution. Also, teachers in category A3 seemed to be mistakenly thinking of variability as “less pattern on Y” or “more fluctuation of bars” in the given context, which is a common misconception in this kind of problems (e.g., Garfield et al., 1999; Isoda & González, 2012).

According to previous research projects (e.g., Shaughnessy, 2007; Isoda & González, 2012), the teachers in the present study showed evidence of harboring five conceptions of variability: (1) *Variability in particular values, including extremes*: focusing on individual data values, such as the extremes of the distribution to calculate the range—e.g., teachers in category A5—; (2) *Variability as distance or difference from some fixed point*: thinking of variability as either a visual or actual measurement of the distance from some measure of center—e.g., some teachers in category A6—; (3) *Variability as the sum of residuals*: thinking of variability in terms of residuals or deviation-based metrics—e.g., some teachers in category A6—; (4) *Variation as distribution*: relating variability to theoretical properties of a distribution and extensive trasnumeration—e.g., some teachers in category A6—; and (5) *Variability as visual cues in the graph*: focusing on visual features of the graph when thinking of variability, instead of actual data values, spreads of data values, or measures of distance or difference—e.g., teachers in categories A2 and A3. Then, only those surveyed teachers who hold conceptions of variability (2), (3) and (4)—i.e., those who fell into category A6—seem to have an aggregate view of data and distribution.

The collected data has led to concerns about the competence base of the participants regarding the statistical topics they are required to teach. Reforms in teacher education programs and training in statistics appear to be essential in the case of Venezuelan secondary school mathematics teachers, in order to prepare them to play an essential role in promoting statistically literate students.

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