IMPROVING THE TEACHING OF STATISTICS IN EARLY GRADES THROUGH TECHNOLOGY-ENHANCED LEARNING ENVIRONMENTS

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The research discussed in the paper comes from a multifaceted program for the teaching and learning of early statistical reasoning in Cyprus. The overall aim of the program is to enhance the quality of statistics education offered in Cypriot elementary schools by facilitating professional development of teachers using exemplary technological and educational tools and resources. As part of the program, professional development seminars for the teaching of statistics with the use of Tinkerplots@ *- a dynamic data-visualization package designed specifically for young learners - were designed and offered to elementary school teachers. The article discusses insights gained from the seminars regarding the ways in which computer visualization tools can enhance teachers' content and pedagogical knowledge of statistics.*

INTRODUCTION

It is now widely recognized by leaders in mathematics education that the foundations for statistical reasoning should be built in the earliest years of schooling rather than being reserved for high school or university studies (NCTM, 2000). Statistics has already been established as a vital part of the K-12 mathematics curriculum in many countries. However, inadequate attention has been paid to one of the most important factors in any educational change – the change in teaching practices. There is substantial evidence of poor understanding and insufficient preparation to teach statistical concepts among both pre-service and practicing teachers (Carnel, 1997). Most teachers are likely to have weak understanding of the statistical concepts they are expected to teach and relatively deterministic epistemological sets, often sharing the same misconceptions regarding the stochastic as their students. As a result, they tend to focus their instruction on the procedural aspects of statistics, and not on conceptual understanding.

The article presents some of the insights gained from a multifaceted professional development program targeting elementary school teachers in Cyprus. The program aims to enhance teachers' pedagogical and content knowledge of statistics through exposure to contemporary technological and educational tools and exemplary materials and resources.

STUDY METHODOLOGY

At an initial stage, we designed a line of research-based instructional materials for the development of early statistical reasoning that meet curriculum objectives for elementary school, and are embedded in contexts familiar to Cypriot children. Central to this design was the functional integration of technology with core curricular ideas, and specifically the integration of the statistics software *Tinkerplots*@ (Konold, 2005). *Tinkerplots* is a recently developed dynamic data-visualization package intended primarily for elementary and middle grades. The software offers an easy-to-learn interface that encourages interactivity and empowers students through exploration, simulation, and dynamic visualization of data, to investigate and understand abstract statistical concepts. Through performing simple actions such as ordering or sorting data, students can develop a wide variety of both standard and unconventional displays. They can progressively organize data to answer their questions. Using features such as differences in icon size, color, and sound, they can even engage in genuine data analysis with multivariate datasets from the start.

Next, we designed and organized professional development seminars for the teaching of statistics with the use of technology. The design of the seminars was based on current pedagogical methodologies utilizing statistical investigation, exploration and collaboration. Acknowledging the fact that teachers are at the heart of any educational reform effort, the program aimed to offer high-quality experiences to Cypriot elementary school teachers that would enable them to effectively integrate technology into their teaching of statistical concepts and ideas.

Twelve teachers (9 females, 3 males) from urban schools in the Nicosia area participated in the professional development seminars, which took place in Spring 2005 and lasted for three weeks. Teachers varied in their level of comfort with computers. Some had knowledge of only the basic computer applications, while others were very proficient with technology. The teachers also had varied background in statistics. Some had very limited exposure to statistics and had never formally studied the subject, while others had taken at least one university-based statistics course.

The emphasis during the seminars was on enriching the participants' content and pedagogical knowledge of statistics by exposing them to similar kinds of learning situations, technologies, and curricula to those they should employ in their own classroom. Teachers worked in group activities to explore a variety of datasets using *Tinkerplots*. Through computer-based experimentation, intensive use of simulations and visualizations, feedback from each other and reflection, we helped teachers to gain better understanding of some of the bedrock statistical concepts that should be integrated into the mathematics curriculum. In addition to computer activities, there were also discussions focusing on children's learning. We explored a broad range of topics of interest to the statistics teacher, including curriculum issues (e.g., role of statistics in the national and European mathematics curricula) and statistics education research (development of statistical reasoning in children, common student misconceptions, etc.). Teachers brought in examples based on their own experiences and suggested ways in which their students' learning could be enhanced by using the tools provided by *Tinkerplots*.

The research team employed various forms of naturalistic research methods (participant observation, videotaping of group activities and whole-class discussions, mini-interviews with teachers, samples of teacher work) to collect data on the development of teachers' confidence and ability to work with the topic of statistics using technology.

The program is ongoing. We plan, during the current school year to conduct a teaching intervention, led by some of the teachers that had attended the seminars. These teachers will customize and expand upon the materials provided to them, and will apply them in their own classrooms with the support of the design team. Findings of this study will inform the revision of the initial instructional and curricular materials as well as the development of a series of teacher support materials. These materials will be distributed in the Cypriot educational community.

MAIN FINDINGS

The analysis of the data collected during the seminars has provided us with rich insights into how teachers think and learn about statistics and how technology might impact their statistical reasoning and, subsequently, their teaching practices and their students' learning.

The results of the study confirm earlier findings of the research literature indicating that teachers have a weak knowledge base in statistics. When first coming to the professional development seminars, most of the teachers did not seem to have a global view of the features of a data distribution. They knew how to calculate measures like the mean and the median, but did not have a robust image of what these measures mean or how they are used (Hammerman and Rubin, 2003). When analyzing or interpreting data distributions, they focused on measures of center and avoided to take variation into account. Such an approach is not adequate since meaningful statistical analysis necessitates integration of the ideas of center and spread.

During the seminars, teachers' endeavors with *Tinkerplots* brought about important changes in their ways of approaching statistical problems. The presence of the software increased their interest in actively pursuing problems involving data. We also have evidence for higher cognitive involvement, for improved comprehension of statistical concepts. All of the teachers, regardless of statistical background, became fully engaged in data explorations. They were enthusiastic about *Tinkerplots* and the tools it affords for delving deeply into the data to make sense of the situation at hand, and expressed eagerness to use it in their classroom. At the same time, use of technology affected teachers' perceptions of data. Through their continuous participation in a variety of interesting computer activities that elicited conceptions of variability and difference rather than center and sameness, they "discovered the richness and complexity of

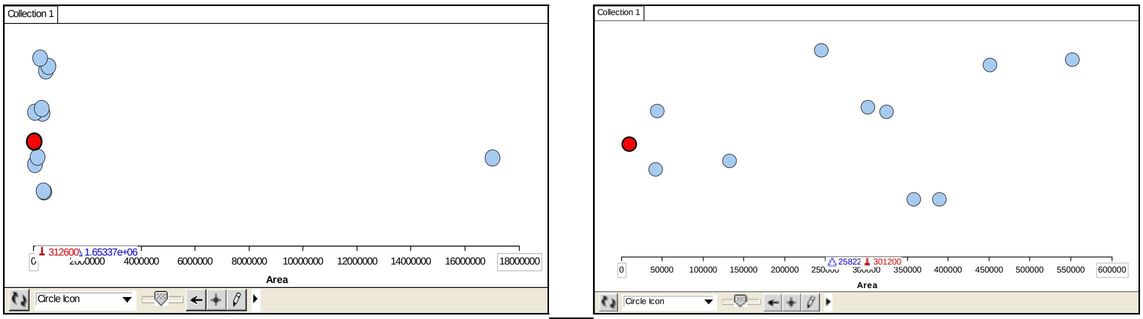

Figure 1: Dotplots of European countries' total area, before and after omitting Russia

data" (Hammerman and Rubin, 2003). This contributed towards improved understanding of statistical concepts and particularly of the ideas of variation and distribution.

We present here an example representative of the activities used during the seminars and of the types of interaction teachers had with technology. This short example illustrates how use of the dynamic statistics software could drastically change the culture of the mathematics classroom and support the development of students' data literacy skills by providing access to tools that allow one to see and manipulate data in ways that are impossible without technology (Hammerman and Rubin, 2003).

"Population in Europe" Task

The "Population in Europe" task appears in the 5th grade mathematics textbook (ages 10-11). In this task, students are given a table representing information about twelve European countries, and are asked to calculate overall means for different variables (e.g., area, population, literacy rate, etc.) and to compare them to the corresponding values for Cyprus. This activity is indicative of the type of tasks through which 5th grade students in Cyprus develop their understanding of the notion of the mean of a dataset. Although the table contains plentiful information and lends itself to rich data analysis, students are only asked to calculate and compare means. While students learn how to compute the mean, they do not get the opportunity to explore how this measure should be interpreted in the context of other characteristics of the data.

Teachers were asked to approach the task first using traditional paper-and-pencil means, and subsequently, the dynamic statistics package. Our goal was to investigate the role of the dynamic statistics tool in shaping teachers' approaches and strategies. We were interested in what effect the visualizations available in *Tinkerplots* would have on their perceptions of center, spread, and distribution. Thus, our data analysis paid particular attention to the processes teachers used when they were actually solving this problem with and without the help of *Tinkerplots*.

Our analysis of the data revealed important differences in teachers' approaches to the problem. During the paper-and-pencil stage, they focused primarily on numeric strategies. They perceived the provided table as a way to obtain the numbers needed to calculate the means and respond to the task questions. None of the teachers took the initiative to investigate the problem situation visually by constructing a graph to gain a better perspective in solving the problem.

Teachers employed very different strategies during the software-assisted stage. Use of technology provided the means for them to focus on statistical exploration and not on recipes and formal derivations, which became secondary in importance. At this stage, teachers did not limit their analysis to calculating means like they did during the paper-and-pencil stage. In order to get better understanding of the problem situation, they now explored the entire distribution of data values using a combination of visual and numerical strategies. These explorations went much beyond the task requirements and generated more questions for teachers to investigate. They made conjectures about observed trends, and actively searched for evidence to support their claims by creating, transforming, and interpreting graphical data representations. Using a variety of techniques afforded by *Tinkerplots* like categorizing data into a small number of bins, imposing cut points, or clumping similar values together and declaring them the same, teachers were able to view and manipulate the data, to make comparisons, and draw conclusions.

In Figure 1, we see an example characteristic of how students approached the task during the software-assisted stage. It shows how two of the teachers went about exploring the variable "country area." While during the paper and pencil stage all they did was to simply calculate the overall mean area and to compare it to the area of Cyprus, access to technology allowed them to make much more sophisticated comparisons. By plotting a dotplot of the twelve countries' area (Figure 1-left) they noted that, with the exception of Russia, all the other European nations appear to have about the same size. Pointing out that this is misleading (*"Cyprus* [the highlighted point in Figure 1] *does not have the same area as England or France!"*), they looked more closely into the plot and realized that the reason it looked misleading was Russia's huge area, which made the rest of the countries appear close together on the graph and also made the mean area increase considerably. They noticed that the mean area (the point marked with a triangle in Figure 1-left) has a value exceeding the area of all countries in the dataset other than Russia and concluded that the median (the point marked with a line) is a better summary of the "typical" area of a European country. They decided to delete Russia and see what effect this would have on the values of the mean and the median. Deleting the data point corresponding to Russia changed the scale of the graph, while the mean decreased from 1 653 370 km^2 to 258 220 km^2 (see Figure 1-right) and approached the median, the value of which decreased only slightly (from 312 600 km^2 to 301 200 km^2). The two teachers concluded that, in this context, deleting the case corresponding to Russia makes the mean a more informative measure of the center of a distribution.

CONCLUSIONS

Data literacy has become a fundamental skill for living in an information era where important decisions are made based on available data. In order for students to develop robust data literacy skills, there ought to be significant changes to the instructional methods and tools employed in statistics instruction. In particular, technology should assume a much more central role. The new family of educational software that came to be known as dynamic statistics software open new potentials in statistics teaching, providing the tools necessary to teach statistics in a manner aligned to the current technological environment we live in. Findings of the current study are very encouraging. They suggest that exposure, during the professional development seminars, to the dynamic statistics software *Tinkerplots* brought about important changes in the participating teachers' approaches to statistics and its instruction. The presence of the dynamic software increased teachers' interest in statistical investigation, it gave them the opportunity to explore data in ways that had not been possible for them before. We witnessed the emergence of a community of highly motivated educators, enthusiastic about the affordances the software offers for delving deeply into the data. Being convinced that instructional use of *Tinkerplots* could lead students to the construction of much more powerful understandings of statistical concepts, these teachers were eager to employ the software in their own classroom.

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