AN OVERVIEW OF THE USE OF TECHNOLOGY FOR TEACHING STATISTICS BY MEXICAN HIGH SCHOOL TEACHERS

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This article presents an overview of the kinds of technological tools used for teaching statistics and how Mexican high school teachers use them. A qualitative approach was adopted based on a survey and interviews. The survey was administered to 754 teachers to explore, among other things, the types of technology they use. Interviews were held with three of the teachers surveyed to probe details related to: (a) the activities in which they use technology; (b) the objectives pursued; and (c) their difficulties in using technology. Although 96% of the teachers report that they use technological tools for teaching statistics, the interviewed teachers emphasized using technology to perform calculations and construct tables and graphs, while also pointing out that they lacked access to technology in their schools.

INTRODUCTION

The use of technology in statistics education has impacted both the content taught and how it is presented (Chance et al., 2007; Hawkins, 1996). Technological tools available currently (e.g., statistical software packages, spreadsheets, applications, graphing calculators, educational software) can help teachers to facilitate students' development of a better understanding of abstract statistical concepts and processes (e.g., confidence intervals, estimated *p*-values, sampling distribution, regression), largely due to the potential of the graphic and data visualization techniques that some tools offer (Tishkovskaya & Lancaster, 2012).

A broad corpus of research reports on the potential of technological tools for teaching and learning statistics (e.g., Burrill, 2019; Garfield & Burrill, 1996; Pratt et al., 2011). It is commonly recognized in research that technological tools can enhance students' statistical reasoning (e.g., Biehler et al., 2013; Chance et al., 2007) and statistical thinking (see Bargagliotti et al., 2020; GAISE College Report ASA Revision Committee, 2016). Nevertheless, the use of technology may be inappropriate. for example, if teachers emphasize computation but neglect the understanding of statistical concepts. A focus on computation reduces learning to simple techniques without developing the reasoning behind statistical methods (Batanero & Borovcnik, 2016). In addition, the type of technology that a teacher uses can affect the processes of teaching and learning statistics because available programs vary in scope, power, and ease of use (Hawkins, 1996).

Bargagliotti et al. (2020) recognize that the integration of technology into the curriculum is a challenge; however, they also note that its use is increasingly necessary and is now considered inseparable from statistical practice. It is in this context that this article reports the results of a study that provide a current overview of the technological tools used by high school teachers in Mexico to teach statistics, the activities in which the tools are used, the objectives pursued, and the difficulties faced by the teachers.

THE STUDY

In 2018–2019, as part of a wider research project, a questionnaire was administered to statistics teachers in high schools in the metropolitan area of Mexico City. A total of 413 schools from 12 different educational subsystems were visited to interview a total of 754 teachers (see Gómez-Blancarte et al., 2021). One item explored the technological tools that teachers used in their classes to teach statistics (see Figure 1), and four items explored how they integrated those tools (see Table 1). Approximately two years after the conclusion of the project, a second study was developed with the objective of deepening results from the items that focused on technology. In this second project, 25 of the teachers who responded to the survey and worked in schools in one of the 12 aforementioned educational systems were invited to be interviewed. The selection of the 25 teachers was based on the ease of obtaining their institutional e-mail addresses because they belong to the same educational system in which the author works. However, of those 25 teachers, only three (hereinafter Teacher 1, Teacher 2, and Teacher 3) responded to the invitation and agreed to be interviewed. These three teachers work on different campuses but with the same curriculum because they are employed in the same educational

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system. Teachers 1 and 2 had 35 years or more of experience teaching high school statistics at the time the survey was administered, and Teacher 3 had between 5 and 9 years of experience. Teachers 1 and 3 have master's degrees, and Teacher 2 has a bachelor's degree. Teacher 1 indicated that statistics is his primary area of expertise, and Teacher 2 stated that statistics is not one of his areas of expertise but that he has sufficient knowledge. Teacher 3 indicated that statistics is one of his secondary areas of expertise.

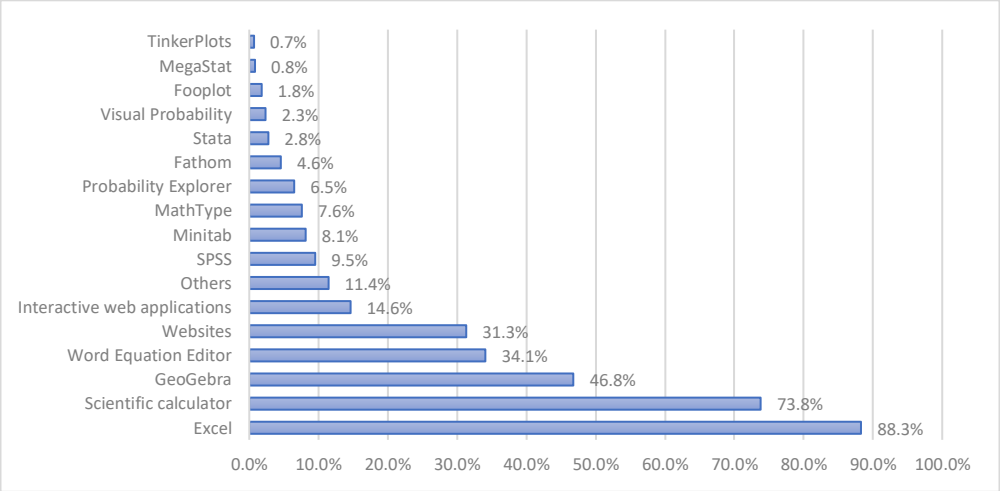

Figure 1. Technological tools used by teachers to teach statistics

Table 1. Uses of technological tools

Response / Use	Exploring data	Interpreting statistical results	Understanding statistical concepts	Performing calculation procedures
Never	1.5%	1.4%	2.8%	1.0%
Just below what is indispensable	13.8%	13.4%	18.8%	13%
Just what is indispensable	46.7%	42.2%	43.9%	45.1%
Much more than what is indispensable	37.8%	42.6%	34%	40.8%

The interview was semi-structured to generate a conversation regarding: (a) the activities in which the teachers use technology in their statistics classes; (b) the objectives they pursue when using technology; and (c) the difficulties they have encountered when teaching with the support of technology. The interview instrument was used as expressed by De Freitas et al. (2017): "as part of a survey method where more information is needed than can be gained from a questionnaire" (p. 168).

The researcher responsible for both projects (author) interviewed the teachers individually through virtual communication tools: Skype (Teacher 3), Teams (Teacher 1), and Zoom (Teacher 2). Each interview was recorded with the authorization of the teachers. The results presented in the following sections are from the analysis of the questionnaire items and interview, which were carried out in Spanish then translated and transcribed by the author. The interview data were analyzed using videotape methodology suggestions: listening attentively to the video, transcribing, identifying critical events, and composing a narrative (Powell et al., 2003). The critical events correspond to the teachers' precise answers to each of the questions posed. With these events was constructed the narrative shown in this article.

RESULTS

Results of the Questionnaire

Of the 754 teachers who were administered the questionnaire from the 2018–2019 study, nine did not answer the questions and 20 indicated that they do not use technology in their statistics classes. Thus, 725 teachers reported using at least one technological tool in their classrooms. As Figure 1 shows,

Excel and scientific calculators are the technological tools most often used, whereas educational software packages such as Probability Explorer, Fathom, and TinkerPlots have much lower usage.

The results of the types of use (see Table 1) indicate that most teachers seem to use technological tools more than is essential. Results derived from the interview provide additional details on these uses.

Interview Results: (a) Activities in Which Teachers Use Technology

The three teachers who were interviewed use such tools as Excel, calculators, and the Alcula web application (http://www.alcula.com). The activities in which they use these technologies encourage students to explore data that might be provided by the teacher or gathered by the students themselves. Teacher 1 stated that he uses a textbook (see Salazar et al., 2011) that offers two types of activities: didactic sequences called "deduce and learn" and integrative units that are "research projects." Unlike Teacher 1, Teacher 2 pointed out that he performs some simulation activities, such as generating random numbers using the calculator. He also uses the calculator to have students work on statistical measurement calculations, and he uses Excel for exercises in elaborating graphs. Teacher 3, meanwhile, mentioned using the Alcula web application. Unlike Teachers 1 and 2, Teacher 3 usually works with data sets no larger than 50. The data usually come from the textbook (see Levin & Rubin, 2004) he uses.

- Teacher 1: [Shows the book] We have here [in the book] some activities called "deduce and learn." These activities allow students, from the beginning of the book, to record the height of the students. They are told that they are going to form teams of five students, what material they need, and how many people they need to measure to obtain their height. In a second activity, they will be asked to follow the same procedure, but recording people's weight. We let them have 400 data to process because it is no longer easy for them to add and subtract. It's easier for them to go to an Excel sheet [where] they can enter the data and then process all the information. That's the idea of using Excel. We use the Casio calculator a little bit ...
- Teacher 2: ... we give them activities in which they must simulate ... for example, using the coin, but once ... the coin is not enough for them, we suggest they use the random number in their calculator. Another type of exercise we use is for them to make graphs. They have a certain command of Office tools such as Excel. Especially, we take advantage of it so they can work at home, we can't do it at school. In essence, there are at least two things I use: the calculator with random numbers, Excel for graphs [and] frequency distributions and, well, we use the calculator so they can directly calculate standard deviation [and] variance, which is also cumbersome.
- Teacher 3: ... They [students] enter the data manually here [points to the Alcula page and the option for data entry] … Because of the [students'] level, I don't analyze more than 50 pieces of data … I use Levin's book, *Statistics for Management and Economics*. I obtain the data, the information, from this book. They're usually case studies.

Interview Results: (b) The Objectives Teachers Pursue When Using Technology

When asked directly about his objectives in using technology for teaching statistics, Teacher 1 acknowledged that although technology is more interesting to students, his main goal is to "be up to date" in its use so that students learn to use it appropriately. Teachers 2 and 3 agreed about using technology to avoid manual calculations and stated that this would facilitate focusing on the interpretation of results. Teacher 2 pointed out that the curriculum emphasizes procedures (e.g., making frequency tables, using formulas to obtain measures of center and dispersion for both grouped and non-grouped data) over interpreting results, which justifies why he pays little attention to such interpretation.

- Teacher 1: It's more interesting for the students to use technology. The purpose of using technology is to be up to date because it's obvious that high school or college students must use Excel in their professional lives. We are interested in them using calculators; for example, the Casio with 508 functions and does not use [referring to the student] the memories, …, does not use the statistics it has, so we bring them closer to this ...
- Teacher 2: The objective is to avoid the cumbersome methods we use for calculation, doing it by hand is terrible, it takes a lot of time. The fact that we use technology reduces our time by almost half. If you do it by hand on a distribution table, it takes almost two hours of work. The other

[objective] is that it would help more to interpret the data, read the data, read the graphs, which we do very little. We're more concerned with what they can do, what they are able to do, and our curriculum indicates this. They put a lot of emphasis on [students' learning] to make frequency tables, knowing the formulas or expressions to obtain variance, standard deviation, mean, median, and mode for grouped and non-grouped data, I think we spend more time on this than on the interpretation of these parameters.

- Teacher 3: The objective that I pursue using technology is that students [achieve] an understanding —real understanding—of statistics, not [just] a theoretical or practical understanding … that they see the importance of statistics in practice, not so much in terms of the theoretical part like 'I can calculate this,' 'I can calculate that.' I mean, that's fine, but the problem is: 'Well. I know how to calculate, but I don't know how to apply it.'

Teacher 1 agreed with Teacher 2 that their curriculum seems to limit them because they must teach all of the content, which leaves little (or no) time to conduct in-depth statistical analyses. "The analysis is short because we must cover a curriculum, so we can't spend too much time doing statistical analysis." To learn more about the analysis that Teacher 1 promotes, he was asked the type of questions he poses to interpret graphs. He responded, "For example, what's the average? What's the mode? How is it represented. So they understand the effect of variance."

Unlike his colleagues, Teacher 3 emphasized his interest in using technology because he believes it may help students to focus on interpreting statistical results and using them in decision-making.

- Teacher 3: I try hard to involve them [students] in this part of decision-making. That's why I'm interested in using technology. It's not so much because it makes calculations easier. I've told them 'You guys are living in a time, or were born in a time, in which calculations is no longer enough because if they hire me, no matter how good I was in school, they're not hiring me to calculate a standard deviation, or a mean, or to see the area under the curve, they'll hire me to give a proposal. Every company already has its programs, they just enter the data, hit enter, and get the result. The question is, 'what do I do with that result?' That's how I save time in class. I do teach them to do manual calculations as well, but of the 100% of class time the important thing for me is 30% calculation and 70% or 60% the interpretation that they [the students] give me.

Interview Results: (c) Teachers' Difficulties in Using Technology

Access to technology in their schools was the difficulty on which all three teachers agreed. Few classrooms in these schools are equipped with technological tools. Some schools have computer rooms where students can work, but it is more common for students to complete work using technology at home. This lack of access to technology also refers to the type of technological tools available. For example, Teacher 2 mentioned that he only has access to calculators and Excel, and very rarely uses programs such as SPSS and Minitab. The teachers also mentioned that they have "little preparation" for using technology in teaching statistics (Teacher 2), and that high school students "are not all that interested in learning" (Teacher 3).

- Teacher 1: … definitely, in the classroom there's no equipment. What I do is bring a projector [and] my computer [so] I can work a little on Excel. But usually that work is for home or over there in the center. There are some computers in the library so student can work on them, but usually it's homework …
- Teacher 2: The first [thing] is that we don't have access to technology other than the calculator or, at home, Excel. Sometimes we do a little with SPSS [and] sometimes Minitab it is. But in essence it's our limited access. There's no way to do it. Another thing is that we need a little preparation, something that bring our educational work closer to the use of technology. Sometimes there are courses, but after that the limitation is again the technology, not having access. We can't take our students to computer rooms. All they have in the classroom are scientific calculators. [So] there are two fundamental things: little preparation for [using of technology] and access to technology.
- Teacher 3: First of all, as I mentioned, the biggest difficulty I have is with resources, because the school doesn't have all the resources in all the classrooms. That's where the biggest difficulty comes from. The other difficulty is the age of the students, who aren't so much interested in learning as in

passing the course. I believe these are the two biggest conditioning factors, at least in my case: not having the appropriate resources and, second, the age of the students.

Given the conditions of access to technological equipment in his school, Teacher 1 expressed that his approach to the use of technology consists in teaching from his computer using a projector to show the work to be done by the students at home.

- Teacher 1: … What I do is bring a projector [and] my computer [so] I can work a little on Excel… They [students] have to do all their processing there and bring it to me, often saved on a memory stick, and we look at it in the classroom [to] we see what they've done.

CONCLUSIONS AND FINAL REMARKS

This research offers an overview of the types and uses of technological tools for teaching statistics by Mexican teachers who teach courses on statistics and probability in high schools. According to our survey, 96% of teachers use at least one technological tool in teaching these subjects. These interviews allowed us to corroborate that the types of technology used by teachers coincide with those mentioned most often in the survey: Excel and a scientific calculator. It seems, however, that these technological tools are not used very often due to the difficulties involved in accessing such technology. Moreover, when they are used the focus is on organizing and representing data, computing statistics, and constructing tables and graphs, coinciding more with the kind of use called "Performing calculation procedures."

The teachers' use of technological tools partially coincides with one of the suggestions put forth by Carver and colleagues (GAISE College Report ASA Revision Committee, 2016): to "perform routine computations using technology to allow greater emphasis on interpretations of results" (p. 20). Although teachers recognize the importance of using technology to interpret statistical results, they admit that they tend to pay little attention to interpretation because their curriculum focuses on performing statistical calculations and procedures. The time they save using technology is usually spent on covering the programmed topics.

According to Batanero and Borovcnik (2016), the teachers who were interviewed may be making inappropriate use of technology because they emphasize computation while apparently neglecting the understanding of statistical concepts. Two conditions may be fostering this inappropriate use: the lack of teacher training and the type of technological tools they use. In relation to the first condition, teachers need to be better prepared in order to go beyond required curricular content. Teachers are required to teach that content, but in practice they can address it as they see fit. To do so requires strategies to approach content in a more integrated way with the support of technological tools to "develop an understanding of statistics and to carry out statistical investigations" (Bargagliotti et al., 2020, p. 73). Statistical projects, for example, are a means of conducting statistical investigations through a process that encourages the integration of statistical content to be addressed by the teacher, including unscheduled content (Gómez-Blancarte & Santana, 2018). With respect to the second condition, as Hawkins (1996) states, the type of technology that a teacher uses can affect the teaching-learning process. Excel is among the most useful tools for organizing and representing data, computing statistics, and constructing tables and graphs. We must, however, offer teachers other options, such as technological tools that do not distract attention from calculations and are readily accessible in their language.

Although the results of the research indicate an urgent need to search for mechanisms to support teachers in their efforts to enhance the use of technology for teaching statistics, they also show that each teacher's vision of the study of statistics is key. Teacher 3 made this clear when he stated that his interest in using technology is to have students focus more on understanding statical results so they can see their importance for decision-making. Although his vision is the correct one, he needs better technological tools and conditions to use them in order to achieve it.

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