

## RESEARCH ON STATISTICAL PROJECTS: LOOKING FOR THE DEVELOPMENT OF STATISTICAL LITERACY, REASONING AND THINKING

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*Research on statistical education recognizes that projects in this field are important instruments for evaluating students' learning, as both a form of authentic assessment and a means for them to experience statistical research. They also constitute a teaching method that leads to achievement and improves students' learning of statistics. However, while implementing statistical projects has had positive results in terms of engaging and motivating learning, there is little evidence of its importance in developing statistical literacy, reasoning and thinking. Since these three elements are crucial learning outcomes of statistics education, this article examines how studies of statistical projects have addressed these goals –implicitly or explicitly– based on a review of research. Preliminary findings suggest that the projects' centrality requires further discussion.*

### INTRODUCTION

In statistics education, projects are recognized as an important tool for evaluating certain aspects of students' learning and for helping them experience the different stages involved in proposing and resolving a statistical problem (delMas, Garfield, Ooms & Chance, 2007; Franklin et al., 2007; Garfield & Ben-Zvi, 2008; American Statistical Association [ASA], 2016). They are also widely-accepted as an effective teaching strategy for learning statistics (Batanero y Díaz, 2005; Ojeda, 2011), and an ideal means of providing learning experiences and reflections on statistical investigations (MacGillivray & Pereira-Mendoza, 2011; Makar & Fielding-Wells, 2011). Indeed, research results demonstrate that incorporating projects into teaching attracts students' attention and induces a high level of motivation (Bilgin, Newbery & Petocz, 2015), because working with projects makes it possible to move statistics out of the classroom, contextualize its application, and illustrate the usefulness of this discipline (Verhoeven, 2013).

Based on a critical review of research, this paper presents an analysis of the learning outcomes that are promoted through the use of statistical projects (SP). Specifically, it explores how developing SP promotes statistical literacy, reasoning and thinking, the three desired learning outcomes for students immersed in statistics instruction (delMas, 2002; Ben-Zvi & Garfield, 2004; Garfield & Ben-Zvi, 2008; Garfield, 2011). In order to identify how SP address those learning outcomes, we examine one of the five criteria proposed by Thomas (2000) as necessary for a project to be considered an instance of Project-Based Learning (PBL); namely, the *centrality* criteria. A project's centrality is related to two corollaries, which we interpret from the discipline of statistics: 1) students encounter and learn the central concepts of this discipline by developing projects; and 2) what they learn is integral to the discipline.

### FRAMEWORK

Based on certain theoretical definitions and distinctions related to statistical literacy (SL), reasoning (SR) and thinking (ST), we elaborated a preliminary framework to identify the type of learning promoted –explicitly or implicitly– through SP (see Table 1). Since these three learning outcomes (SL, SR and ST) share similar processes, our framework does not make an absolute distinction; rather, it summarizes what we think SP may reveal in terms of promoting one type of learning more than another.

Table 1. Distinguishing among Statistical Literacy, Reasoning and Thinking practices in the development of SP

SL practices	SR practices	ST practices
<ul style="list-style-type: none"> <li>• SP promote the elements of knowledge proposed by Gal (2002): That is, literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions.</li> <li>• The project activities (e.g., data collection, analysis and interpretation) demand a minimum, but significant, knowledge of basic statistical concepts and procedures.</li> <li>• Project development is oriented towards providing students with a general idea about the usefulness of statistics in various real-life contexts.</li> </ul>	<ul style="list-style-type: none"> <li>• SP activities challenge students to explain “why a particular result is expected, or has occurred, or why it is appropriate to select a particular model or representation” (delMas, 2004, p. 85).</li> <li>• The selection of statistical models or analyses depends highly on context.</li> <li>• SP emphasize the conceptual development and application of statistical procedures and ideas.</li> </ul>	<ul style="list-style-type: none"> <li>• The project is oriented towards helping students develop a certain level of expertise in solving real-world problems in real contexts.</li> <li>• SP activities include practices for critiquing and evaluating results (Ben-Zvi &amp; Garfield, 2004).</li> <li>• Students are faced with professional and personal decisions to apply statistical knowledge (Phannkuch &amp; Wild, 2004; delMas, 2004).</li> </ul>

**METHOD**

For our literature review, we applied the documentary research method (*i.e.*, the analysis of documents that contain information on the phenomenon under study, Bailey, 1994) to analyze research papers pertaining to SP. By limiting the scope of the review, we were able to focus on texts by authors who described their work as “SP” and not “statistical investigation”. We searched various sources of information, including international research journals, (e.g., *J. Stat. Educ.*, *Stat. Educ. Res. J.*, *Am Stat*), conference proceedings (e.g., ICOTS, IASE), and Doctoral and Masters’ theses (e.g., from the Universities of Colorado and California). We also reviewed other databases, including Google Scholar and Redalyc. The keywords used in our search included: “statistical projects”, “project method” and “project-based learning”, and our approach included searches for references within the selected papers. The review covered publications between 1994 and 2016 and included texts in Spanish and English. We found 90 papers, 67 of which were analyzed for this article.

## RESULTS

Due to space limitations, in this section we cite only examples from the few research articles (of a total of 67 reviewed) that provide sufficient detail regarding the development of the SP to allow us to identify the learning goals that were promoted and the centrality criteria applied.

### *Statistical Literacy*

The SP reported by Biajone (2006) and Conti & Carvalho (2014) satisfied all the centrality criteria and exhibited similar SL practices. Both show that statistical content was presented and taught to the students as their needs emerged during development of the different project phases (centrality criteria), and that the knowledge they acquired and the skills they developed pertain to the discipline. Biajone planned his statistics course for Pedagogy students, while Conti & Carvalho worked with 7<sup>th</sup>-grade students in a Youth and Adult Education Program (aged 16-43). Development of the SP was carried out in a similar way: first, the students chose the main topic for the project, then they were divided into small groups to investigate sub-themes or aspects related to that topic. Basically, the SP were developed in five phases that promote specific literacy practices.

- 1) Defining the project topic. Students began by studying printed material or Internet sites to understand the topic and help them posit a few questions about it that would serve to make up the questionnaire. This phase tested students' literacy skills and context knowledge.
- 2) Planning actions. Students were guided in the formulation of questions to construct a questionnaire, which was divided into the sub-themes of the main topic. Because this involved using such basic statistical techniques as random sampling, it promoted statistical knowledge.
- 3) Taking actions (data collection, organization, presentation and description). Once the questionnaire had been applied, each group cleaned up and organized the responses received according to the sub-themes. Data was organized using conventional tables (e.g., a frequency table) and presented in the form of graphs (e.g., bar charts and circular graphs). In addition to the statistical knowledge promoted, students were challenged to use some mathematical knowledge (e.g., calculating frequencies and percentages, and performing arithmetical operations).
- 4) Data analysis and conclusions. In order to extend data analysis and interpretation, other statistical concepts –statistical summaries, for example– were presented to the students. The data analysis reported by Biajone (2006), for instance, included average, median and mode. He states that each group utilized these three measures to arrive at their final conclusions.
- 5) Presentation of results. Students presented their work orally, either to the group or to the entire school community. In the case of Conti & Carvalho's work (2014) students used posters to display their results in the form of tables and graphs. The school community was encouraged to participate by observing those materials and then asking students questions about their results. In this phase, students interpreted their statistical results in relation to the wider context.

### *Statistical Reasoning*

The SP reported by Bailey, Spence & Sinn (2013) exemplify the main SR practices promoted through the four phases of project development. Since the project became the principle means through which those (undergraduate) students learned the topics addressed in that statistics course (centrality criteria), they did not select the type of analysis needed for the project. Rather, they were motivated to reflect upon the statistical ideas involved in two types of analysis that were stipulated in advance: linear regression and comparison of means using t-tests.

- 1) In the planning phase, the instructor aided the students in identifying the appropriate variables for working with the two types of projects assigned (linear regression and comparison of means using t-tests), and in articulating a research question concerning those variables. According to Bailey et al. (2013), students worked in groups. Each one chose its own topic and then produced a written plan that included “at a minimum, their research question, definition of variables, data collection

- plan, expected results (e.g., positive or negative correlation), and relevant details of the planned analysis (e.g., matched pairs or independent samples design)” (p. 6).
- 2) Data collection phase. Students selected their data collection method from three options that were analyzed: surveys, observations and measurements, and Internet data. In this phase, they were challenged to utilize various elements of statistics: survey questions, the notion of construct, examples of variables, procedures for measuring, distinguishing between population and sample, and randomness.
  - 3) The analysis phase entailed applying descriptive techniques (e.g., descriptive statistics, histograms and box plots) with both the linear regression and comparison of means using t-tests approaches. Some basic requirements were prescribed for each project. For instance, for the linear regression projects, students were required to calculate, interpret and discuss the correlation coefficient  $r$ , the squares regression line, and the coefficient of determination, while for the t-test comparison projects they had to identify the appropriate t-test design and suitable null and alternative hypotheses, and run the specified t-test correctly. Instructors have the option to expand the list of requirements.
  - 4) Report phase. Each team wrote and gave an in-class presentation of their final project report, in which they had to present details about the research question and the data collection method used and provide summary statistics for the sample data, appropriate charts, a summary of the analysis, and conclusions in context. Their presentations ended with a discussion period.

We consider this research to be a case that promotes SR, because during all four phases of project development the students were challenged to provide statistical reasons and justifications strictly related to the two analyses specified: linear regression and comparison of means using t-tests.

#### *Statistical Thinking*

The SP that we identified as promoting ST learning goals entailed students resolving real problems through interaction with real clients (e.g., Martonosi & Williams, 2016; Bilgin, Newbery & Petcoz, 2015). These SP were embedded in “statistical capstone courses” of a broader statistics curriculum (centrality criteria). The students involved in these SP were encouraged to think critically and act as statistical consultants in order to solve challenging problems of real clients. Martonosi and Williams report four instances of projects (standalone capstone project, statistical consultancy, project within a statistical methodology course, and instructional capstone course). Though they have pedagogical differences, “[w]hat is common to these different types of capstones is that they help students grow as practitioners through their use of real data and emphasis on professional skill development” (p. 129). In general, these projects asked students to apply statistics to real problems, synthesize all the steps of a statistical analysis (from data acquisition and learning to model interpretation), evaluate their results, and communicate their process and results to clients.

We consider that these SP serve to develop ST, because the knowledge that students develop constitutes a meaningful way of becoming a statistician. They provide practices through which students can become experts.

#### CONCLUSIONS AND IMPLICATIONS

We have reported part of a broader research initiative that we are carrying out on the topic of SP. For this report, we set out to identify certain features that inform us as to precisely what kind of learning is developed through work with SP, and the particular way in which SP are conceived. We now offer some preliminary conclusions.

- There is evidence that the use of SP is a fairly popular method for assessing students’ learning, since we found that approximately 80% of the projects reviewed had been used as a means for students to apply, reinforce or demonstrate what they learn in class. In this sense, we can corroborate that SP constitute useful assessment methods for statistical education.
- According to the centrality criteria, however, with few exceptions SP are peripheral to the basic curriculum because they are not considered central to the teaching process. In order to confirm

that SP can function as a central teaching strategy, we based our evaluation on explicit evidence from the reports reviewed, such as: “the foreseen discipline topics were taught through and for the development of the project” (Biajone, 2006, p. 2); “the project group method was added to the curriculum as a fixed part of the ‘Introductory Statistics’ course” (Verhoeven, 2011, p. 1); “It is important to note that the projects were intended to be the primary vehicle through which these topics were taught, rather than a mechanism to synthesize the topics after they had already been covered.” (Bailey et al., 2013, p. 4). Since clarifications such as these are not common in the papers reviewed, we attempted to identify the centrality criteria implicitly, but this was rarely feasible. Finally, we observed that when SP were applied as the central teaching tool they were also used to evaluate students’ learning.

- In relation to the three learning outcomes (SL, SR and ST), we found that SP used either as an assessment method or the central teaching strategy tended to mobilize important practices related to each outcome, though this mobilization differs in each case. While as an assessment method SP only allow instructors to identify what students can and cannot do with what they have learned, using them as a central teaching tool makes it possible to ascertain what students need to learn in order to meet project goals. According to Thomas (2000), when a project is used only for students to apply knowledge already learned, it serves as an exercise, so learning outcomes are limited to the application of the statistical concepts and processes acquired.

Finally, we would highlight two important benefits of SP as a central teaching strategy:

1. Work with projects can enrich curricula. Obviously, the situation of teaching statistics in schools varies from one country to another, but this discipline often forms part of study programs in the field of mathematics (Batanero, Burril & Reading, 2011). This means, on the one hand, that statistical topics are minimal in number compared to those of other sub-fields (e.g., algebra or geometry); and, on the other, that they tend to be atomized. Working with SP thus represents a strategy that can enrich curricula because each phase involved in developing a project entails the use of various statistical concepts and processes that go beyond the topics normally included in curricula. In this regard, Thomas (2000) points out that at the PBL projects *are* the curriculum. Moreover, working with projects foments the integration of different statistical concepts and processes that need to be combined to achieve project objectives; in this sense, it propitiates a less fragmented teaching approach.
2. The learning outcomes –SL, RL or ST– can be adequately addressed since they can be used as the foundation of projects. In this regard, we consider it necessary to focus attention on the aspects of statistical knowledge involved in these learning experiences, not just on the aspects of motivation, attitude or disposition; for example, analyzing what is learned in terms of a more conceptual understanding of statistical ideas, and not just what is done, or how students operate during work with projects.

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