TEACHING STATISTICS THROUGH LEARNING PROJECTS

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ABSTRACT

This paper aims to reflect on the teaching of statistics through student research, in the form of projects carried out by students on self-selected topics. The paper reports on a study carried out with two undergraduate classes using a methodology of teaching that we call 'learning projects'. Monitoring the development of the various stages of the learning projects allowed continuous adjustment of the process and provided an insight into the benefits and limitations of this approach. Important aspects included the complexity of the group relationships, the importance of choosing the topic of the research, data collection and time management. Students carried out an evaluation of the process, and the resulting information was analysed using quantitative and qualitative approaches.

Keywords: *Statistics education research; Undergraduate research; Collective subject discourse*

1. INTRODUCTION

Our digital society is replete with information and technology. It demands statistical knowledge for data analysis, and statistical skills to summarize, interpret, and disseminate the resulting information. Many researchers have conducted studies on the process of teaching and learning these statistical skills and knowledge, including: Batanero (2001), Campos, Coutinho & Almouloud (2006), Cazorla (2004), delMas (2002), Gal (2002), Garfield & Ben-Zvi (2008). There seems to be consensus about the importance of rethinking how we design educational practice and implement alternative ways of learning. Practices that prepare the student to "… learn how to learn throughout life ... [and encourage] the development of the capacity for independent learning and thinking" (Castells, 2003, p. 227) are especially important in a fast-changing world.

The Statistics Education Research Group of the Federal University of Rio Grande (FURG), Brazil, has been investigating how to prepare undergraduate students for their future professional role in this reality of constantly-changing information that requires ongoing learning from each person. The activities of this group are grounded in Piaget's (1976) theory of Genetic Epistemology and Maturana and Varela's (2005) Theory of Cognition.

We believe that learning improves when we take account of individuals' experiences and their interactions with their environment. As Maturana and Varela (2005) state, this interaction is a requirement for learning, as it enables the effective participation of each student. We need to ensure that the practices and strategies of teaching incorporate such interactions – an approach that does not always occur in statistics pedagogy. Before judging students as uninterested or unprepared, we should consider whether such student behavior originated in the teaching method. According to Piaget (1976), every student could display logical reasoning if his or her activity is encouraged and affective inhibitions are removed. Methods of 'active learning' seem able to encourage the required learning.

It is difficult to read reports about the poor state of statistics learning, and difficult to observe in our daily practice as undergraduate professors, unmotivated students giving up on statistics courses. Garfield (1993) recommends the use of group learning activities to encourage the students to construct statistical knowledge for themselves. Of course, this requires a change in the professor's role, moving from information transmission to guidance of students' learning processes.

With this theoretical background, this paper presents an option for statistics pedagogy: the use of 'learning projects'. This is a dialogical teaching approach which can remove emotional inhibitions of students who are fearful of calculations involved in statistics and encourage them to interact among themselves and learn via a team approach. This methodology has been adapted from Fagundes, Sato, and Laurino-Maçada (1999) specifically to the teaching of statistics. It begins with the process of researching for information to satisfy students' curiosity and interests. Depending on the students' questions, having students collect and analyze the data will create a network of meanings for them, and thus promote their learning.

The creative research involved in a learning project, starting with the planning of the investigation, describing the phenomenon to be investigated, choosing the type of sampling, and selecting the statistical method of analysis, can contribute to students' construction of statistical knowledge.

This paper aims to evaluate the lived experience of students learning statistics through learning projects. The approach is particularly useful in introductory statistics courses, as it minimizes the emphasis on calculations and formulas. The approach has been utilized since 1999 by members of the Statistics Education Research Group at FURG, and this report presents the analysis and results of an investigation carried out with two undergraduate courses during 2012. In the following sections. we first give more information on the theoretical background and the methodology of this project. We then describe the results of the quantitative and qualitative investigations, and conclude by discussing their implications.

2. LEARNING THROUGH LEARNING PROJECTS

2.1. THEORETICAL ASPECTS

Teaching statistics via learning projects aims to promote links between topics, discussion and interpretation of results, and reflection on statistical concepts by students themselves. Campos, Wodewotzki, and Jacobini (2011) point out that a characteristic of statistical thinking is the ability to take a global view and to understand interactions in a statistical process. A student who has learned about statistics can explore data and uncover aspects that were not explicit initially. Maturana and Varela's (2005) Theory of Cognition proposes that knowledge has to be actively constructed, developed though interactions between students, their colleagues, their professor, and the environment in which they live. In particular, knowledge is not pre-existent before action, because "... every deed is a knowing and all knowing is a deed" (p. 31). In short, if life is a process of learning, build your own concepts, not in a passive way, but in interaction with others. As Maturana and Varela state: "Learn to live and live to learn" (2005, p. 12).

Maturana (1993, p. 31) sees learning "as a process of adaptation, of accommodation to a condition different from that where the body – the person, the child, the student – was originally." Aware of this, the professor has the task of 'destabilizing' the student and provoking him or her to adapt through structural changes in order to develop other learning. To do this requires change in the organization of teaching and learning, abandoning the old idea that the teacher need only 'teach' a topic in a coherent and organized way for the student to learn.

According to Piaget (1976), the student needs to go through a set of imbalances and rebalances, and build the spiral of his/her own knowledge to achieve new learning by reaching a dynamic equilibrium between assimilation and accommodation. Assimilation occurs when the individual uses cognitive structures that have to incorporate new objects to existing schemas, and accommodation occurs when it becomes necessary to change the existing structures, or

even create new ones to incorporate the learning. The alternation between these two complementary processes is responsible for cognitive equilibration, namely learning (see Figure 1).

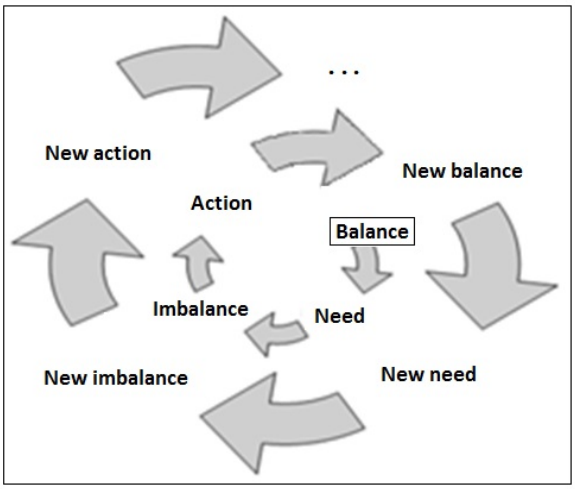

Figure 1. The Process of Equilibration (after Piaget, 1976).

Exchange of experiences is required for the construction and understanding of statistical concepts. In the same way, Gal (2002) points out that for statistical literacy to occur, it is necessary to understand that the statistics are not just numbers, but numbers in a specific context. A statistically literate person should be familiar with the basic concepts of descriptive statistics, probability, and inferential statistics to make decisions. The construction of statistical concepts occurs through the students' actions and interactions, in the context of their own knowledge environment. Each student is subject to his/her own learning process.

2.2. PRACTICAL ASPECTS

Fagundes, Sato, and Laurino-Maçada (1999) define the learning project as a pedagogy that begins with students' previous knowledge in a topic of interest to them, and is built on students' questions – or 'worries' – that arise from their experiences of the topic, and their desire to explain and understand these experiences. The approach encourages students to develop the ability to ask questions, to search for answers, to think critically and construct coherent arguments, and to learn how to learn through their own research.

According to Galiazzi (2003), learning through research allows the student to establish "a dialogue between theory and practice, weaving a network of connections" (p. 52). Moreover, it requires a shift in perception, thoughts, and beliefs, a change that is linked to the process of knowing, which according to Maturana (2006) is built on interactions with the world.

Teaching statistics through learning projects can contribute to cognitive development and can promote learning as it requires the construction rather than the memorization of statistical concepts. The student has the opportunity to experience all phases of a statistical research project, from planning and data collection, to analysis and presentation of results.

Education through research promotes learners' ability to organize their own information and expand its network of meanings. Logical reasoning becomes enhanced while preparing summaries of answers to their questions. According to Fagundes, Sato, and Laurino-Maçada (1999), the first step in developing a learning project is to select a topic that provokes students' curiosity and formulate a research question. An inventory is taken of students' knowledge about the question, classified into (provisional) certainties and (temporary) doubts. During the process of research, the doubts can be clarified and the certainties can be validated.

Work with learning projects develops according to a plan of intensive interaction. The validation of a provisional certainty or the clarification of a provisional doubt requires a process of collecting information, analysis and summary of this information, and discussion and debate about its meaning. In the process, new knowledge will be constructed and new questions will arise, and both of these can be included in the inventory and in the research process.

A learning project can be carried out by an individual or a group of students. With groups it is important that all participants share a curiosity about and an interest in the same topic. Using group work provides opportunity for discussion of ideas and promotes dynamic learning through cooperation among students. A network of cooperation is established around the learning project, formed by the participants in the project, students working on other projects, teachers in the role of mentors, and any external collaborators. Students build a network of knowledge around the question under investigation.

Working with learning projects, the professor as tutor assumes different roles in the interaction with students (Fagundes, Sato, & Laurino-Maçada, 1999). These could be to help students select an area of common interest, articulate objectives, and negotiate different learning styles. He or she also has to set up conditions that encourage interaction between group members, in person or using digital media. Other roles are to facilitate students' search for information, to make connections between students' interests and statistical concepts, to encourage and coordinate the reflection, and to analyze continually the progress of the learning. The professor provokes students to think critically by asking appropriate questions, presenting challenges, and putting forward counter-arguments to their views. According to Franco (1997), the professor may also be responsible for helping to establish contacts with experts from different disciplines, as required by the project, while also promoting integration between statistics and other areas of knowledge.

3. METHODOLOGY

The methodology of learning projects was adapted for use in statistics classes. In this experience with two undergraduate courses during 2012, the first part of the teaching was carried out as usual, , introducing various statistical topics and concepts to students in an expository way. Following this, learning projects were introduced as a strategy that combined an area of practical and personal interest to students with the development of the statistical topics described in the course objectives.

The first step was choice of project topics by the students. At this point the professor acted as 'provocateur', articulating students' interests and beginning the process of listing the doubts and certainties about the particular topic chosen. Then each student explained his or her interest in the topic to the other students. Fellow students who were also interested in the topic sometimes dropped their initial suggestion and became part of the group for the topic. Thus, the groups were formed not by personal affinities, but by students' interests in the topic to be researched. Eventually, the group of students made a new list of doubts and certainties on the particular topic.

The next stage was to carry out a literature review, in papers, theses, web sites, and books. These bibliographic findings, doubts and certainties were used to set up a data collection instrument. With the guidance of the professor, this survey instrument included a variety of variables, nominal and ordinal qualitative, discrete and continuous quantitative, to illustrate all aspects of the course.

The survey was then used to collect data, applying students' recently-gained knowledge about methods of sampling. At this stage of the learning project, the professor had the important role of reminding students of the statistical concepts required for carrying out the project, concepts such as tabulation and organization of data, calculation of summary statistics, and analysis and interpretation of collected data. This integration between topics and data analysis aimed to increase students' statistical literacy.

A total of 110 students participated in a learning project, and 70 of them contributed to an evaluation of the process. The sample group comprised 50% females, had a mean age of 25.1 years with standard deviation of 6.4 years, and most were working (76%). Some students had

studied statistics previously at school (36%), some were taking a statistics course for the first time (38%), and others were repeating this course (16%).

An important aspect of this approach was the student-student and student-professor interactions, designed to build skills and statistical competencies. At the conclusion of the project, each group of students presented a written report on their project, consisting of: an introduction to the chosen topic, objectives, characterization of the population and sample, statistical analysis performed with the collected data, discussion of results, conclusions and references. At the end of the statistics course, each group made an oral and visual presentation of its learning project to the whole class. The final assessment of the statistics course was comprised of 30% for the learning project, 10% for class work, and 60% for a written examination.

An end-of-course evaluation of students' views about the learning approach was carried out. Both closed-form and open-ended questions were used. In the closed-form questions, students evaluated the phases of the learning project on a scale from 0 (very difficult) to 10 (very easy): choice of topic/theme, choice of appropriate sampling, data collection, tabulation of results, presentation of data summaries, discussion of results, writing the final report, working in groups, and overall evaluation of the effectiveness of the learning project for their learning. The open-ended questions were included to explore students' choice of topics, the contribution of the learning project's approach to their understanding of the statistical concepts, and the main difficulties they experienced.

The closed-form questions were analyzed using standard statistical summaries. A multiple regression model was built (using stepwise forward selection) to investigate which stages had the greatest effect on their overall evaluation.

The analysis of the open-ended questions was carried out using Collective Subject Discourse (or CSD, which is Discurso do Sujeito Coletivo or DSC, in Portuguese). This qualitative research technique is used to analyse spoken or written material by identifying the central ideas in the discourse of individual participants and using them to construct a 'synthetic discourse' – a statement that combines the ideas and words of different people into a text that is presented in the form of a statement from an individual person (Lefèvre, 2005; Lefèvre & Lefèvre, 2005). The approach begins by identifying key ideas and phrases in each individual statement, then combines the list of key ideas into one list, and finally creates a collective statement that combines the most important ideas of all participants. Oliveira, Pereira, and Stewien (2005) point out that discourses constructed from key expressions from different participants represent, in a collective way, the thoughts of a group of students who participated in the same educational experience.

4. RESULTS

Students' scores for various stages of the learning project show that they found the choice of appropriate sampling the most difficult (lowest mean 5.7 and standard deviation 2.0), followed by data collection and tabulation of results (each with mean 5.9). On the other hand, the highest means were obtained for choice of topic/theme and working in groups (each with mean 6.7), though working with groups had the highest standard deviation (3.1) indicating less consensus among students about this aspect. Figure 2 shows the distribution of scores for each aspect of the learning projects; it seems apparent that students had quite varied views about the difficulty of each aspect.

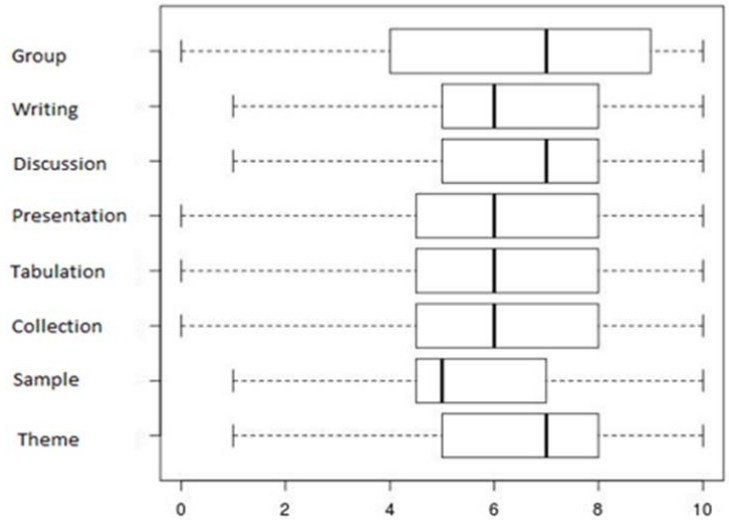

Figure 2. Boxplots of Scores for Aspects of the Learning Projects.

The multiple regression analysis investigated the relationship between scores for different aspects of the learning projects and the score for the overall evaluation. Table 1 shows that presentation of data summaries, choice of topic/theme, and working in groups are the constructs that significantly affect overall performance in the project. These three aspects of the learning project explain almost three-quarters of the variability in overall performance (R^2 = 0.71). Normality of residuals from the model was established using the Kolmogorov-Smirnov test (p > 0.20).

Table 1. Multiple regression model

Aspect	Beta	Standard error	p
Presentation of data summaries	0.443	0.085	< 0.0001
Choice of topic/theme	0.314	0.074	< 0.0001
Working in groups	0.335	0.082	< 0.0001

This result highlights the need for greater intervention by the professor in the other aspects of the project, so that they would also make a significant contribution to the overall realization of the learning project. The model also points out the importance of the teamwork aspect; the periodic and recurrent dialogue between students enables them, according to Garfield (1993, 2013), to exchange experiences and ideas, and develop the group cohesion and socialization during the learning process.

The results of the Collective Subject Discourse are presented next. Each central idea is highlighted in the analysis of the open-ended questions of the evaluation instrument. This analysis helped us to understand better students' perceptions about the process of carrying out learning projects, and the contribution of this form of study in helping them learn about the statistical concepts. Table 2 presents the main ideas for each question. The quoted discourse is constructed from individual students' contributions answering the open-ended evaluation questions. Each quote is presented as if it originated from an individual person.

Table 2. Main ideas identified during the Collective Subject Discourse (CSD)

Question 1 – What led you to choose the research subject?	
Central idea: Engagement with the subject/theme	CSD: Involvement, curiosity and personal interest in the subject, which is also part of the everyday life of people in general, and therefore relevant.
Central Idea: Easiness	CSD: The theme was selected taking into consideration the ease of defining the population, access to data and/or the application of questionnaires, highlighting the lack of time of students who work during the day and study at night.
Question 2 – Did the research help you to improve the understanding of statistical concepts involved in collecting, organizing and presenting data? Explain.	
Central idea: It helped in the understanding of statistical concepts	CSD: The research made us get involved in the subject, to think more about it. We had to go back to study the topics mentioned in the course and which enabled a better understanding, and realize that everything may be associated. The research led us to search about our doubts, to solve them, and also to improve what we have learned at class. It led us to transform numbers in texts. Through the learning project we could understand more clearly the information and ideas without distortion, it also helped us in creating graphs, interpretation, and especially the analysis of results. Moreover, it was possible to understand the system which is behind a research project, since the development of the research introduced situations that we had not thought of, making the concepts used in class more meaningful and closer to our reality.
Central idea: It somewhat helped in understanding of statistical concepts.	CSD: In this research I learned a little more about these statistical concepts, but still not enough for me. I still find difficulties to distinguish some concepts. Some concepts taught in class were oblivious by the time of the research. Since we work eight hours a day, it was difficult to study having to think about the project, so the research was divided and each member of the group worked on a part.
Question 3 – List the main difficulties encountered in carrying out on the research.	
Central idea: Lack of spirit of cooperation.	CSD: In the beginning of the research process it was very hard. We had difficulties in choosing the topic. We lost a lot of time with the literature review and in the last days, before delivering the research was when we really got into the statistical calculations, which, for me, was the real purpose of the research. It was difficult to organize schedules for all members, considering that most classmates don't have much time outside of the classroom. It makes it more difficult to perform this kind of research. The lack of commitment, dedication, interaction and cooperation of some classmates hindered the achievement of group research. It led us to see that this type of activity needs to be done for all the students together, not each one doing separated. Getting respondents to participate was also difficult; we asked lots of people, but not all of them were willing to take part.

5. DISCUSSION

The regression analysis showed that presentation of data summaries had the greatest impact on the overall evaluation of the learning project, followed by the group work and the choice of topic/theme. In the presentation of data summaries, students had the opportunity to investigate many of the concepts studied in the course, including the graphical and tabular presentation of data, as well as calculation of percentages, means, standard deviations and other statistical measures. Some groups explored the calculation of probabilities in their analysis. This stage – data presentation – had one of the lowest means (6.1) on the students' evaluation, which shows that this was one of the most difficult phases for students, although the wide variety of scores showed that there was no consensus on this point. Some students reported in the CSD that learning methods of data analysis was the main focus of their learning project.

The multiple regression analysis showed that the choice of topic was also significant in the overall evaluation of the project. To Ponte, Brunheira, Abrantes, and Bastos (1998), the project must be based on a theme selected according to the students' preferences and personal styles, one that is relevant to their practice. Only then will the project be relevant to all participants so that they are co-accountable for its completion. However, in the CSD it was observed that some students chose a topic on the basis of ease of access to the target population and data collection, rather than on the basis of their interest.

In our study, learning through research was characterized by a productive learning situation, in which students could select and study a topic of their choice, and enhance their learning of specific statistical concepts. It gave students the opportunity to eliminate provisional doubts and confirm temporary certainties. For Prado (2006), designing and implementing a learning project demands a personal involvement, and an ability to manage complex situations. Nevertheless, it can be a stimulating challenge for students who are willing to take an active role in their learning process and the development of their professional skills. In addition, the learning project promoted a contextualized discussion of topics presented in the course, enabled students to acquire specific knowledge in their topic area, as well as experience of interpersonal relationships and social communication. Such a pedagogical approach has an interdisciplinary character. However, the paradigm shift can be a challenge for professors: it is hard to abandon an expository teaching model rooted in traditional practice and replace it with a student-learning centered model.

Carrying out the learning project gave students opportunity to develop a range of generic professional skills. During the investigations, students often found themselves in unexpected situations where they had to solve problems and resolve doubts. The ability to deal with such situations is a desirable characteristic in the profile of every good professional. According to Kenski (1998,), in teamwork "time and space are experimentation and audacity in the search for ways and possible alternatives, dialogues and exchanges of the knowledge at hand, of permanent recycling of everything and everyon." (p. 68).

Many groups were able to manage the time constraints of their research, taking account of each member's availability to carry out the projects effectively (this was reported by 83% of the students). However, other groups had problems, due to the fact that most students work and hence find it difficult to schedule group meetings. In some cases, this provoked disagreement between group members, prompting some groups to opt for division of labor in the learning project. Perhaps this explained why some students were unable to see the relationships between statistical concepts and practice that are so necessary to the learning project methodology. The absence of dialogue with classmates may also have contributed to the difficulties. When each student is responsible for a part of the project, without the possibility of helping others build their knowledge, they may feel that the experience of the learning project does not contribute significantly to their development and learning (such a view was reported by 17% of the students). Other statistics educators have come to similar conclusions (e.g., Sisto & Petocz, 2012).

Maturana (1993) emphasizes the importance of understanding the educational space as a social space, a space of experimentation and dialogue, in which students can develop and build their understanding. It is also a transformative space, in which students and teachers will adapt themselves through continual interactions. A group learning activity allows the student to interact with other classmates, to carry out cooperative work, and to face up to disagreements and conflicts. Garfield (1993, 2013) argues that cooperative work improves communication skills and the ability to work in teams, and enables students to restructure new statistical concepts by adding them to their own cognitive structures.

The results of both of this paper's analyses – the statistical and the discourse – show the importance of including more than theory and exercises in a statistics class. Through the medium of a learning project, students gained experience in all phases of a statistical investigation, as well as the construction of statistical concepts. The research also highlighted the importance of groupwork skills and their importance in contemporary networked society.

6. FINAL THOUGHTS

In monitoring the development of the learning projects, we noticed a need for constant reflection about the development of our teaching practice, to identify the limits of the approach and to seek new opportunities for improvement. We must keep in mind students' reaction to (and assessment of) the process.

Using the students' discourse, we were able to confirm that the learning projects promoted an association between statistical concepts and practical applications. Students were involved in conducting actual research, and becoming authors of a report. Their own choice of topics brought meaning and significance to the activities they performed and enhanced their participation. However, we did observe that some students had difficulty applying concepts learned in the classroom to their learning project. It is important to incorporate into the pedagogical approach the theoretical foundations of Piaget and Maturana and Varela, particularly the interaction between students and opportunities to construct their own knowledge. Presentation of isolated topics by a teacher makes only a small contribution to students' construction of statistical concepts.

A lack of time and cooperation among students eventually led some groups to opt for a division of tasks, an approach that reduces the level of mutual support for the work. Although advances in digital technology are transforming the flexibility of time and space in teaching and learning, there is still a need for personal interaction in the educational process.

Teaching through research in undergraduate statistics courses seems to have great potential for statistics pedagogy. While the current study points out several aspects that could be improved, the inherent uncertainty in this method contributes to the education of individuals with well-developed initiative, autonomy, awareness of contemporary problems, sensitivity to working with others, and flexibility for dealing with the unexpected in a fast-changing world.

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