A METHODOLOGICAL STRATEGY FOR ACTIVE LEARNING IN MULTIVARIATE ANALYSIS.

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ABSTRACT

This paper describes the design and implementation of a methodological strategy for putting active learning activities into practice in the discussion session of the Multivariate Analysis course of the Industrial Engineering program at the Universidad Católica de la Santísima Concepción, UCSC. Learning multivariate methods is a challenging task for undergraduate students. They not only have to know, understand and assimilate those statistical concepts underlying each statistical method, but they also must be able to develop statistical thinking, interpret statistical results in different application contexts and acquire the skills to use those statistical software that nowadays are widely used in business and industry. Thus, we decided to implement active learning through small-group work. To this end, we redesigned the case studies given to students for the discussion sessions. A more holistic structure combines practical problems, statistical background and results in an integrated format. To evaluate the impact of this strategy, we designed a pre-intervention survey and a post-intervention survey as assessment tools of the active learning method. The pre-intervention survey was distributed in discussion sessions using a traditional lecturing style whereas the post-intervention survey was distributed in sessions using an active learning approach. Results indicate that 77.78% of students like working in small groups with peers to solve the problems posed in the discussion sessions. Only 6.35% of students disagree or strongly disagree working in small groups. In general terms, students are more motivated to learn multivariate methods through small group work with peers.

KEYWORDS

Active learning, multivariate analysis, small-group work, cooperative learning, large courses, Standard 8

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INTRODUCTION

Nowadays, engineers are called to solve many different problems, not only in industries or companies, but in any institutions where they are currently working. Engineering students develop a set of learning outcomes and skills during their college years. As problem solvers, they must develop an outstanding capacity for abstraction, understanding of different contexts, and strong technical skills –among others– to be able to choose and apply a proper analytical tool to solve a specific problem. The Multivariate Analysis course offers students the opportunity to learn statistical methods toward this perspective and to develop statistical thinking (Garfield et al. 2010). Students have to understand the underlying statistical theory and concepts, learn how to apply these methods when solving real problems, how to use statistical software and, most importantly, how to interpret results from both the statistical theory and real application perspectives to be able to make good decisions. At this level, engineering students must develop statistical thinking and “integrate statistical and contextual knowledge” (Bidgood, 2010, p. 155, Garfield et al., 2010, Jolliffe, 2010).

The Multivariate Analysis course is structured as lectures, discussion sessions and laboratories. Lectures give students the fundamentals of statistical methods and interpretation. Discussion sessions help students strengthen their multivariate techniques results interpretation skills. The goal of the laboratory is for students to learn to use diverse statistical software, such as R-Project, SAS and the data analysis functionalities of MS Excel. The syllabus of the course is organized in such a way that for each multivariate topic, students attend a set of activities composed of a lecture, a discussion session and a laboratory. A set of case studies relevant for the industrial engineering program is prepared for each sequence and distributed to students in advance. Both lectures and discussion sessions have been traditionally given as lectures but with intensive interaction between lecturer and students.

On the other hand, in 2011, the Industrial Engineering program at the Universidad Católica de la Santísima Concepción began implementing a curricular reform based on the CDIO approach (Loyer et al., 2011), in which the program's courses must gradually meet the standards and levels defined in the CDIO model. Keeping in mind a future CDIO certification, it was decided to reach level 3 of Standard 8, "teaching and learning based on active experiential learning methods" in several courses in two years' time. Level 3 is defined as “active learning methods are being implemented across the curriculum” (CDIO Standards v2.0, 2010) Thus, in a first step toward reaching said Standard 8 level, this paper describes the design and implementation of case studies through small-group work as a methodological strategy for putting active learning activities into practice in the discussion session of the Multivariate Analysis course of the Industrial Engineering program.

This paper is organized as follows. First, we give a brief background of definitions and strategies of active learning methodologies in introductory statistical courses. Next, we describe how we design and implement the case studies through small-group work as an active learning strategy in the discussion sessions of the Multivariate Analysis course. Then, we report the results of a survey on the perceptions of students about the new methodology to finally give remarks about advantages and disadvantages of the new strategy, the necessity of assessment instruments and future works.

CASE STUDIES AS AN ACTIVE LEARNING STRATEGY

Active learning activities involve engaging students in the learning process, making them think through practical experiences (Pinheiro & Simões, 2012). Active learning turns out to be a constructivist way of learning new knowledge (Garfield, 1993), and allows students to develop other skills and attitudes such as learning how to learn, teamwork and improvement of communication skills (Loyer et al., 2011).

Muñoz et al (2013) describe different methodological strategies for promoting active learning such as conceptual questions, case studies and discussion in small working groups, debates and brainstorming, among others, which seek to develop students' personal and interpersonal skills. Case studies are particularly useful for enabling students to analyze situations from different perspectives (Kimonen & Nevalainen, 2005) and to develop meaningful learning. This helps students easily identify, analyze and prioritize conceptual elements and, as a consequence, acquire skills to relate theoretical concepts in real applications (Iahad et al., 2013). On the other hand, Johnson & Johnson (1994) distinguish the difference between those objectives that can be achieved individually from those that can be achieved through cooperative learning. The authors state that individual learning outcomes can be achieved through cooperative learning into small-group work. Thus, it should be a favored cooperative learning approach that also fosters the development of creativity, and of personal and interpersonal skills.

From the standpoint of statistics, methodologies for promoting active learning in students have been widely used in secondary education and introductory statistical courses (Garfield, 1993 and references therein, Smith and College, 1998 and references therein). Garfield (1993) reported her experiences on applying small-group cooperative learning as an active learning strategy in introductory statistical courses. She mentions that –besides improving the understanding of statistical concepts and theory– small-group activities improve student productivity, attitudes and achievements as well as attendance and class participation (Jones, 1991 in Garfield, 1993). From a case study or cooperative learning approach, the instructor's role changes from traditional lecturer to being a facilitator of the learning process. Thus, instructors should face the course considering different resources to support positive interdependence among students, and guide and encourage discussions on topics (Johnson & Johnson, 1994). Working with informal or formal cooperative groups, lecturers can easily identify the achievement of learning outcomes through positive interdependence focused on the task and responsibilities, interaction between students, individual and group responsibility in accordance with the assignment of tasks or roles, teamwork, and delivering results at the group level (Smith et al, 2005).

The implementation of active learning methods in the teaching of statistics for engineering programs is a challenge, and literature reporting results in this context is scarce, all the more in the teaching of advanced subjects such as Multivariate Analysis. Recently, Lopez and Gross (2008) reported the application of active learning methodologies to graduate students in space physics education. But, to the best of our knowledge, no experiences have been reported for advanced statistics courses.

DESIGNING CASE STUDIES THROUGH SMALL-GROUP WORK

To implement an active learning approach in the Multivariate Analysis course, we redesigned the case studies documents given to the students for the discussion sessions. This design allows active student participation in class. The new configuration consists in a structured format including: an introduction with instructions and the description of the case study, a data set, and three sections with information. The three sections contain different results, background and questions. This configuration can be used to create case studies based on each multivariate method and allows the students understanding of practical problems through description, comprehension, application, analysis, synthesis, and evaluation. Figure 1 gives an example of the document structure on discriminant analysis, which has been considered as an experimental case for this research. Instructions present the goals of the session, the document organization and how students have to proceed during the discussion session (Garfield, 1993). Then, we introduce the case study. For the discriminant analysis session, we used a real data set provided by a company from the cellulose industry. The engineer in charge of suppliers wanted to classify them according to environmental and safety variables, service quality and financial performance. Data is already assigned to one of two classes. We describe the training and validation data sets for the three sections. Each section includes –with increasing difficulty level– tables and figures with the results of the applied statistical methods, the underlying statistical theory, and a set of questions to be answered by small groups of students in the discussion sessions. For instance, students have to solve the problem knowing the difference between the minimum expected cost of misclassification rule and the Fisher's approach to classification. Some of the questions or statements posed to students are, "comment on the symmetry or asymmetry of data distributions justifying your answer based on skewness coefficients and histograms" and "suppose data comes from two populations with equal covariance matrices, given the discriminant functions for each class, to analyze which variable has the greatest discriminating power (equal prior probabilities, equal costs)". Different solution strategies may be considered. Thus, we allow students to discuss and select an alternative basing their answers on the statistical results. This new structure seeks to facilitate understanding the relationships between the mathematical background and results using a real-life, relevant engineering problem. We try to prevent students from mechanizing the interpretation of results.

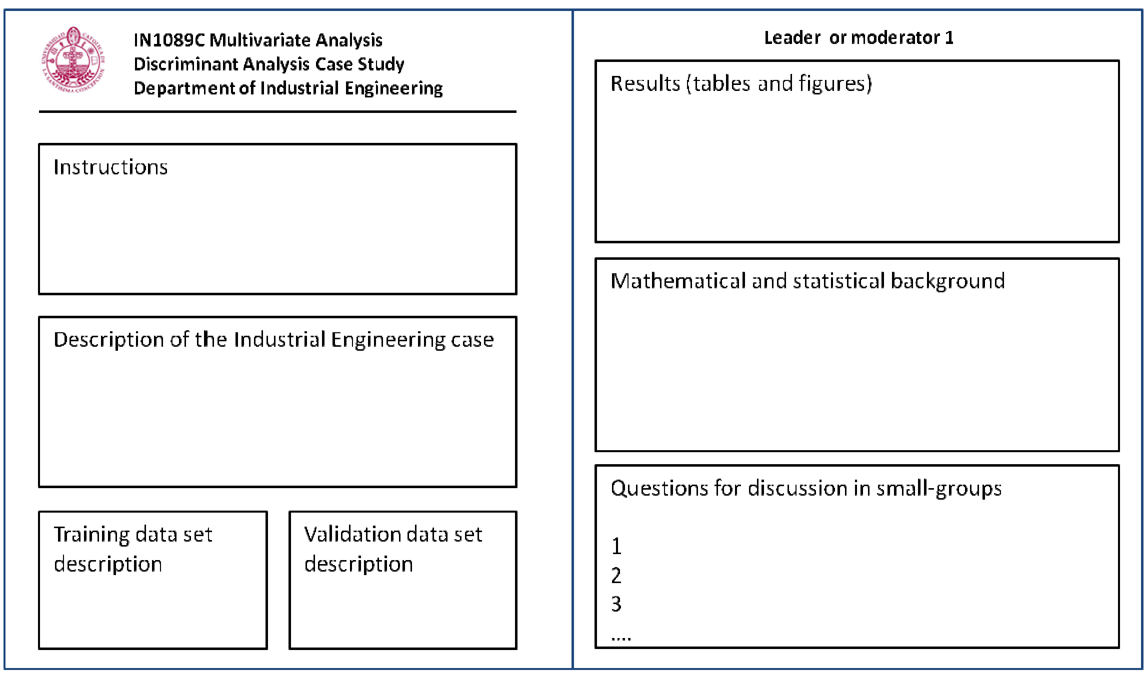

Figure 1. Structure of the discussion session case study document

Multivariate Analysis is a course with a large number of students –we had 112 students attending the course during the second term of 2013, organized in four discussion sessions, of 28 students each. During the discussion sessions, students were divided into groups of three. Each student guides the work of the group in one of the three sections allowing discussion among members. In this environment, instructors must motivate students, creating learning conditions and providing opportunities for small-group work. Main differences between the implemented active learning approach and the classic approach by lecture are that in the former, students are responsible for their own learning process, being in charge of developing tasks to gain knowledge by experience and helping them to understand that the success or failure of their learning also depends on them. Benefits for lecturers are better students work supervision and group feedback (Fernandez, 2006).

STUDENT PERCEPTIONS ABOUT THE NEW METHODOLOGY AND DISCUSSION

To evaluate the impact of the strategy, we designed a short pre-intervention survey and a post-intervention survey to assess the active learning method (case study through small-group work). Thus, we obtained quantitative indicators of success or failure of the methodological strategy. The pre-intervention survey was distributed in the discussion session using a traditional lecturing style whereas the post-intervention survey was distributed in the session using an active learning approach. These surveys aimed to assess two main aspects: student satisfaction with both traditional and active learning methodologies, and student perception about their achieved learning outcomes. The surveys considered a five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree). Table 1 shows the number and percentage of respondents to the pre-post intervention surveys.

Comparing the Pre-post Intervention Surveys Results

According to the opinions of the students, the document structure was welcomed and is useful to students, and the case studies were considered interesting. Also, students prefer to work with peers in small groups instead of the traditional lecturing style for the discussion sessions. In what follows we detail some of our results.

Table 1. Number and Percentage of Respondents

	Answers	%
Pre-intervention	57	50.89
Post-intervention	63	56.25

Problem Understanding and Time

Results indicate that 68.42% of students reported they could understand the problem statement when the instructor was using a traditional lecturing style (*survey question: At the beginning of the class, I have understood the problem statement watching and reading the problem on the screen and listening to the information given by the instructor*). Meanwhile, this percentage is higher when the instructor uses an active learning approach. 74.6% of students agree or strongly agree with the statement that they understand the problem statements when they discuss the case study in small-group work (*survey question: At the beginning of the class, I have understood the problem statement reading it in the case study document and discussing it with my peers in my group work*).

Moreover, 61.90% of students declared they have more time to understand the questions posed in the case study when working in small-groups (*survey question: I have had enough time to understand the posed questions in the case study document*). This contrasts with the result obtained when the instructor uses a traditional style where 50.88% of students agree or strongly agree they have enough time to understand the questions posed in the case study (*survey question: I have had enough time to understand the questions given by the instructor*).

Relating Theoretical Background and Application

Seventy six percent of students agree or strongly agree that working in small groups helps them relate the theoretical concepts reviewed in the lecture to the case study worked in the discussion session. Moreover, 69.84% of students declared they have enough time to relate multivariate theory with results of the real application discussed in small-group work (*survey question: I have had enough time to relate the theoretical concepts reviewed in lectures and the problem results discussed within the small group work*). This percentage is smaller when students attend a lecturing style discussion session: only 54.39% of students agree or strongly agree they have enough time to relate theoretical concepts with the results of the statistical methods (*survey question: I have had enough time to relate the theoretical concepts reviewed in lectures and the information given by the instructor in the discussion session*).

Student Preferences

Students state they like attending discussion sessions to work in groups to discuss the case study. A 77.78% of students agree or strongly agree (*survey question: I like to attend the discussion session to work with my peers and solve the problem proposed by the case study*). In addition, 82.54% of students reported they like discussing the meaning and interpretation of the results (tables and figures) presented in the case study with their peers (*survey question: I like to discuss with my peers the meaning and interpretation of each result*).

FINAL REMARKS

This paper shows that case study through small-group work is a successful active learning strategy for an advanced and large course of statistics; it contributes to the achievement of learning outcomes by the students. We were also able to confirm that students are more motivated to learn multivariate methods when they work with peers in small groups. Some of the benefits are that this strategy offers a more holistic structure and the cases combine a practical problem, statistical background and results in an integrated format. Moreover, the strategy defines clear student roles and responsibilities into the groups, strengthening learning by each individual and by the group as a whole. Lecturer-facilitator role allows students to gain autonomy, self-confidence, and assurance in their own skills and those of their peers to address relevant engineering-multivariate problems.

The new methodology also presents some limitations. The most important weakness is that the document given to students with the description of the case study already includes a lot of information with which students should work. This is beneficial, but also prevents students from building their own statistical solutions to engineering problems. Thus, we consider that our approach should be complemented during the course term, for instance, by asking students to develop a small term project aimed to solve a real problem relevant to Industrial Engineering using a multivariate method.

On the other hand, assessing the impact of the active learning strategy in the student's performance in learning theoretical concepts of statistics and in solving and interpreting practical problems is –in our opinion– an unresolved issue. Traditional assessment methods –such as formative or summative assessments– may measure the achievement of learning outcomes, but cannot quantify the impact of the active learning methodologies in reaching the understanding of subjects and interpretation skills. Future work should include the design and implementation of experiments and tools for this purpose, and move forward in the design of surveys. This seems to us a very challenging task due to the difficulty of separating the effects that multiple factors may have on student performance.

Finally, recall that engineering students are not trained during their undergraduate program to develop statistical thinking. But, from a statistical educator standpoint, engineering students reach a certain level of statistical thinking that should be forested and applied to real world applications.

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