

## INTEGRATING COLLABORATION, COMMUNICATION AND PROBLEM SOLVING TO PROMOTE INNOVATION IN STATISTICS EDUCATION

Carla A Vivacqua<sup>1</sup>, André Luís S de Pinho<sup>1</sup>, Marcus A Nunes<sup>1</sup> and Eric A Vance<sup>2</sup>

<sup>1</sup>Department of Statistics, Federal University of Rio Grande do Norte, Brazil

<sup>2</sup>Department of Applied Mathematics, University of Colorado Boulder, USA  
cavivacqua@gmail.com

*As statistics educators, we need to prepare 21<sup>st</sup> century students for a global society. Besides a theoretical and methodological background in statistics, students need experience in collaboration, communication and problem solving to reach full potential. Statistical collaboration laboratories represent an effective approach to enhance acquisition of such knowledge and skills. Students work in interdisciplinary teams under proper supervision and have opportunity to interact with professionals from different fields to advance research and solve societal problems. They are encouraged to write reports and present results at conferences. Students feel motivated to learn statistical methods and to enhance their professional attitude. We propose that the curriculum includes activities within a statistical collaboration laboratory environment. Furthermore, a network of statistical laboratories provides an opportunity to exchange best practices.*

### INTRODUCTION

Statistics is particularly useful for decision making in many areas, see e.g. PARIS21 (2007), Geller (2011) and Allen et al. (2016). It has become essential to catalog, classify and analyze data that academia, government and the private sector generate in the most diverse fields of knowledge. We increasingly need people prepared to analyze the immense amount of data generated by society today. These people are professionals trained in Statistics.

Despite the importance of Statistics, some students leave their courses without a clear understanding of the role of a statistician in a scientific investigation or in an organization. Statistics has been traditionally taught through examples from textbooks. Although teachers may demonstrate examples of data analysis in the classroom, it is common to deal with ideal situations, which are far from what is happening in the real world. Missing data, tables arranged in different formats, and data collected in an unorthodox manner are seldom discussed in depth. In general, students receive little exposure to important practical organizational, scientific and statistical activities such as gathering of subject-matter knowledge, definition of the objective and design of a study, selection of factors and variables, sample selection, experimental design, data collection, data visualization, and development of statistical models.

Besides learning the theory and methods of statistics, undergraduate and graduate students also need experience in communicating and collaborating with different professionals, as stressed by Vance (2015a). Communication is an invaluable skill these days. If students interact only with peers within the same field, they will be unprepared to deal with the outside world. For this reason, it is necessary that students learn to dialogue with people unfamiliar with statistical jargon, how to ask great questions, and how to listen, paraphrase, and summarize the responses to understand their needs. Furthermore, it is essential that the results obtained in the analyses are presented to the clients in ways the clients will understand and be able to implement. Therefore, students need to know how to translate statistical terms into more accessible language, increasing the clarity of communication, but without losing the rigor of the methodology.

One approach to teaching statistics involves engaging students regularly in all aspects of the process, from the conception of meaningful questions, through design, data collection, analysis, interpretation and reporting of results, see e.g. Marek et al. (2004). Along these lines, statistical collaboration laboratories (stat labs) represent an effective alternative to improve acquisition of such knowledge and skills.

The objective of this paper is to present how a stat lab can enhance statistical education. We briefly discuss the role of statistical laboratories on undergraduate education. Then, we describe a suggestion for the modus operandi of a statistical collaboration laboratory based on our experience on running stat labs at our universities and show a sample of activities that could be included throughout the curriculum of an undergraduate course in statistics.

## ROLE OF STATISTICAL COLLABORATION LABORATORIES

The involvement of educational institutions in community services could help solve societal problems to improve the livelihood of people. Collaboration among the scientific and general communities is crucial to achieve this goal. In this scenario, statisticians can contribute to community service through a statistical laboratory.

According to Vance (2015b), a stat lab could act in three different aspects:

- Train statisticians and data scientists to become effective, interdisciplinary collaborators who can move between theory and practice to solve problems for real-world impact.
- Serve as research infrastructure for researchers and decision-makers to collaborate with statisticians and data scientists to enable and accelerate research and data-based decisions that make a positive impact on society.
- Teach short courses and workshops to improve statistical skills and literacy widely.

Furthermore, as pointed out by Awe and Vance (2014), a network of stat labs could strengthen each other's operations. An example of such a network is the LISA 2020 network, centered at the Laboratory for Interdisciplinary Statistical Analysis (LISA) at the University of Colorado Boulder. This network is comprised of an additional eight stat labs in Africa, the one described below in Brazil, and several affiliate labs in the United States. The LISA 2020 network provides a channel of support to sharpen skills and share best practices via annual symposia, online network hangouts, exchanges of personnel, and a mentoring network of technical experts to assist on projects as needed.

## MODUS OPERANDI OF A STATISTICAL LABORATORY

A stat lab within an educational institution could aim to meet the demands of its academic community, other educational institutions and the private sector that show an interest in benefiting from the incorporation of statistical methods into their processes. Here, we describe a suggestion for the modus operandi of a stat lab considering its partnership with an undergraduate course in Statistics. A similar approach can be adapted to other circumstances. The structure discussed is based on our experiences running the Laboratory of Applied Statistics (LEA), a stat lab at the Department of Statistics of the Federal University of Rio Grande do Norte (UFRN) in Brazil.

The stat lab should have the ability to guide the design of studies, analyze data, optimize processes and assist research development inside and outside the educational institution, thus increasing the diffusion of knowledge in society. The stat lab could be run by the students with a board of professors acting as mentors. Every undergraduate student has to participate in the stat lab for at least two semesters as a condition for graduating as a statistician. Nevertheless, according to our experience in LEA/UFRN, students are voluntarily engaged to the stat lab for more than the required period.

The undergraduate students are the main role players as statistical collaborators at the stat lab. Every semester, all students take part in a training session on statistical collaboration to enhance their communication skills and prepare them to interact and conduct meetings with other professionals and researchers and become more effective scientific collaborators. The methodology used in the training follows Zahn et al. (2013), Aliaga & Gunderson (1996), Hoadley et al. (1990), Chatfield (1988), Hand & Everitt (1987), and Vance (2012). It includes the POWER structure, developed to optimize meetings among collaborators. POWER is the acronym composed by the initials of the following actions: Prepare, Open, Work, End and Reflect. Each of these items has its specific role within the statistical consulting procedure, especially with regard to meetings with collaborators. Students learn how to behave and ask the proper questions in order to extract as much information as possible from the collaborators to meet their expectations.

The students working at the lab could be classified as junior or senior students. Each collaboration client is assigned a team with two students: one junior and one senior collaborator. When a student starts participating in the lab, he or she joins the teams as a junior collaborator. As he or she develops their abilities, they become senior collaborators. A senior collaborator has experience with statistical methods, consulting and the lab's modus operandi. Students lead each statistical collaboration from the first meeting with the client until the presentation of the final report. They are responsible for the communication with the clients, data analysis, development of reports and presentation of results. The whole process is monitored by a mentor, who is a professor

or professional statistician, and guides the activities done by the students. Each team has regular meetings with their mentors to summarize meetings with the clients, discuss methods for data analysis and report progress of activities. There are monthly meetings with the whole team to discuss the activities developed by each team. This is an opportunity for everyone to share their experiences.

After each student’s meeting with the client, the mentor is sought by the team, without the presence of the client, in order to discuss and obtain guidance on the solution approach. The students perform the proper analysis, prepare a report of the results, and a mentor reviews it, leaving it ready for the final meeting with the client. This entire process, from the initial meeting with the client to the delivery of the final report, takes three weeks on average. Requests for collaboration arrive in a continuous flow. The requests are handled in a first-in first-out basis depending on the availability of teams.

In summary, students participating in a stat lab have the opportunity to apply the statistical knowledge obtained during the course, as well as to gain experience applying their communication and collaboration skills. Teachers involved in the activities increase their own experience, enriching the number of examples they provide in their courses. Students and professors from other courses, as well as employees and private entrepreneurs, gain a great ally in the analysis of their problems.

**SAMPLE GUIDELINE ACTIVITIES WITHIN AN UNDERGRADUATE CURRICULUM**

Here we propose guidelines that could be implemented to promote student participation in stat lab activities throughout a four-year program in Statistics with the following characteristics: (i) the first two semesters of the curriculum include basic courses in Statistics, Computer Science and Mathematics; (ii) During the third semester, the students take a course which presents a general overview of several statistical methods; (iii) the remaining semesters are mainly dedicated to the fulfilment of specific statistical courses necessary to provide an adequate training for a statistician.

Beginning in the first semester, the students could participate in the stat lab, under the supervision of qualified instructors, statisticians and senior students. Here we present descriptions of activities within the stat lab that can be performed by the students according to their semester in the undergraduate course in Statistics, and also a brief explanation of the reasons the proposal adds value to the students’ training.

<p><i>Stage 1: First Semester</i></p> <ul style="list-style-type: none"> <li>• Meetings with clients</li> <li>• Preparation of reports on meetings clients</li> <li>• Communication with clients</li> <li>• Preparation of databases in different formats</li> <li>• Exporting and importing data files with R</li> <li>• Analysis with spread sheets</li> </ul>	<p><i>Stage 2: Second and Third Semesters</i></p> <ul style="list-style-type: none"> <li>• All previous activities</li> <li>• Descriptive analyses</li> <li>• Summary reports</li> <li>• Use of R to perform descriptive analyses, identification of outliers and data cleaning</li> <li>• Basic R programming</li> <li>• Written and oral presentation of results</li> </ul>
<p><i>Stage 3: Fourth to Sixth Semesters</i></p> <ul style="list-style-type: none"> <li>• All previous activities</li> <li>• Hypothesis testing</li> <li>• Simple linear regression</li> <li>• Design and analysis of experiments</li> <li>• Sampling</li> </ul>	<p><i>Stage 4: Seventh and Eighth Semesters</i></p> <ul style="list-style-type: none"> <li>• Linear regression</li> <li>• Sampling</li> <li>• Multivariate analysis</li> <li>• Time series</li> <li>• Categorical data analysis</li> </ul>

Purpose of each stage:

Stage 1: development of basic, but essential, skills referring to abilities concerning teamwork; effective communication with peers and clients; learning good listening practice; and fundamentals on spreadsheets, databases and converting files into formats other than the one it is currently in.

Stage 2: development of skills for a more professional written report and oral presentation, use of mid-level programing, importance of adequately using basic statistics to bring life to lifeless data.

Stages 3 and 4: in addition to the previous stages, application of more sophisticated statistical methods, use of advanced programming, tutoring junior students.

Since 2014, these guidelines have been applied in a stat lab in Brazil called Laboratório de Estatística Aplicada (Applied Statistics Laboratory - LEA). This lab is located at the Federal University of Rio Grande do Norte (UFRN), and three of the four authors of this manuscript are involved in running it and mentoring students. Participating in LEA activities for at least two semesters is a mandatory activity for the students enrolled in Statistics BSc at UFRN. The experience at LEA has been overwhelmingly positive for both students and professors. Many students join LEA with almost no communication skills. After they leave their internship and become professionals, they have the appropriate skills to conduct meetings with their clients, colleagues, or supervisors. Besides that, they learn that real data is not organized like in books, and often must be cleaned and organized to be analyzed. Additionally, professors who are advisors in LEA maintain interactions with the market and other areas of academia, learning about their needs and continuously adapting LEA to make the lab an important player in our scientific community.

## CONCLUSION

Besides being an environment for practicing the skills and tools taught during the regular traditional statistics courses, participation in a stat lab motivates students to learn new statistical methods, enhances their professional attitudes, and improves their oral and written communication skills. Students have the opportunity to work in interdisciplinary teams and interact with graduate students, professors, and other professionals to collaborate in advancing research and solving business and societal problems. They can also write reports and present the results of their collaborations at seminars and conferences. Furthermore, students can experience the process of preparing, submitting and publishing papers and are encouraged to do so whenever possible. Moreover, a stat lab provides examples and data from practical applications that can be used to improve the teaching of statistics. By providing opportunities for students and their faculty mentors to communicate and collaborate with various clients to analyze data to solve real problems, statistical collaboration laboratories promote innovation in statistics education and can transform the education and research practice within an entire department.

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