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COMPETENCY BASED EDUCATION AND TECHNOLOGY IN TEACHING STATISTICS

Juan Rositas-Martínez, Universidad Autónoma de Nuevo León, México
Joel Mendoza-Gómez, Universidad Autónoma de Nuevo León, México

ABSTRACT

This research focuses on proposing answers to crucial questions for improving statistics teaching. There is a perception not yet overcome that statistics is abstract, not useful, rigid, that generates anxiety and negative attitudes especially in management science and socials students. Neumann, Hood and Neumann (2013) provide an overview of recent research on teaching and learning statistics. Makar & Ben-Zvi (2011), Gardfield & Ben-Zvi (2007) and Scheaffer (2001) have suggested teaching approaches that include more real-life data and less theory, more data analysis and intuition-based knowledge building supported on active student participation and suitable technology and software. Research findings on how student learns, competency-based education, teamwork and communications and information technologies provide the platform to device and test new answers. Our study reports results achieved in our university (UANL-FACPyA) from an exploratory research. We share these results with all those statistics teachers and instructors in business and industry organizations facing theses challenges.

JEL: A20

KEYWORDS: Statistics Education Research, Teamwork, Competency-Based Education, Statistics Software

INTRODUCTION

Modern societies need competent employees and citizens that may function properly in our information-laden organizations. One critical skill that competent citizens (and future competent citizen, i.e., students) should achieve is statistical literacy. In regard with this concept, statistical literacy is the ability to understand and think critically about data, statistical methods, and results interpretation as *basic skills* or minimal knowledge achieved by all citizens. These skills also include desired habits of mind, attitudes and general awareness, since data variation and chance are omnipresent in modern life (Gal, 2004).

We should expand the statistical literacy concept to include the ability to understand and critically evaluate findings from recent research discussed in newspapers, magazines and journals that can make a substantive difference in personal, professional and policy-making decisions, and in quality of life (Wallman, 2003). Watson (1997) detailed what statistical literacy should include: 1) a basic understanding of probabilistic and statistical terminology; 2) an understanding of statistical language and concepts when they are embedded in the context of wider social discussion; and 3) a questioning attitude one can assume when applying concepts to contradict claims made without proper statistical foundation. A more advanced set of statistical knowledge and skills beyond basic literacy may and should be achieved by some people such as college and graduate students, and even technicians or incumbents of certain industries job, such as manufacturing.

There is a perception not yet overcome that statistics is abstract, not useful, rigid, that generates anxiety and negative attitudes especially in management science and socials students (Neumann, Hood and Neumann, 2013). The issue that we want to introduce here is that even though statistical education is being promoted at all levels at a fast pace, research supporting these efforts has evolved at a much slower rate. Researchers in this area have posed crucial questions. They invite us to propose answers.

Although US government educational agencies since year 2000 recommend that education from kinder-garden through grade 12 should include statistical reasoning, educational research on this area is not substantial and well supported. Evidence research tells us since the 1980´s that many adults cannot handle questions related with probabilistic thinking properly. Neumann, Hood and Neumann (2013) provide an overview of recent research on teaching and learning statistics. Makar & Ben-Zvi (2011), Gardfield & Ben-Zvi (2007) and Scheaffer (2001) have suggested teaching approaches that include more real-life data and less theory, more data analysis and intuition-based knowledge building supported on active student participation and suitable technology and software. What we want to add to the existing body of literature is the validation of the hypothesis that competency-based education supported by technology could improve substantially statistics learning. Our exploratory in-class research focuses on proposing answers to overcome these crucial perceptions and questions when teaching statistics.

The remainder of the document is organized as follows: First, we do a literature review to summarize previous studies related with crucial questions in reference with challenges when teaching Statistics and efforts to face them. Second, we present the methodology based on a conceptual model that we are using to understand and validate the impact of attitude, efforts and other factors in course outcomes, and data we have collected from a 28 students' class experiment, when applying this model and Csikszentmihalyi suggestions to promote positive attitudes. We also present the instruments and statistical methods used to collect and process data and ascertain the impact of efforts in course outcomes. Third, we present the results and findings when applying the methods we have suggested for teaching Statistics, explained in previous section. Fourth, we conclude telling the reader what we have done and achieved that could beneficially add to the existing body of literature.

LITERATURE REVIEW

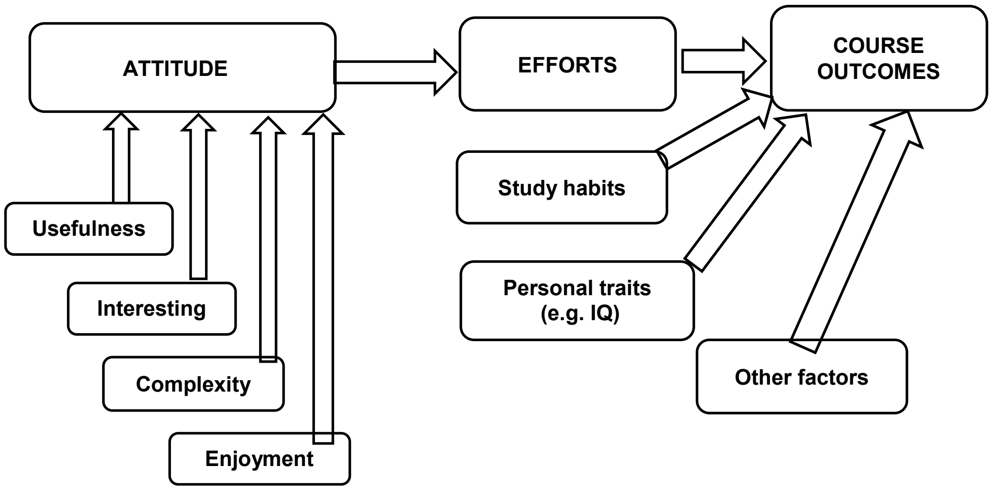
This section summarizes previous studies related with crucial questions in reference with challenges when teaching Statistics and efforts to face them. In line with recent research on teaching and learning statistics, in a statistics course taught in the first semester of 2014, we promote the use of real-life data, since several researchers have suggested implementation of teaching approaches that include more real-life data and less theory (Gardfield and Ben-Zvi, 2007, Scheaffer, 2001, Makar and Ben-Zvi, 2011, Neumann, Hood, and Neuman, 2013). This course has a competency-based approach and specific details are detailed in Appendix.

Conceptual Model: Factors Impacting Course Outcomes

We show in Figure 1 the model that we are using, derived from our literature review, to understand and improve the teaching statistics process. Data collection and statistical analysis in this exploratory research were a collaborative effort done during class sessions.

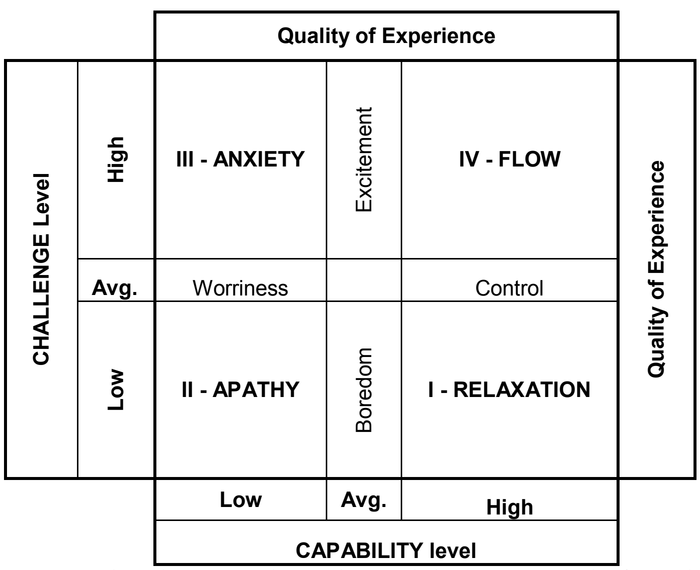
Attitude is very important for attaining *outcomes* but we have inserted *effort* as an intermediate variable between them, as seen in Figure 1. Setting goals, or expected outcomes, plus motivation reflected in *efforts*, leads to developing strategies for achievement, i.e., good grades and skills development. These strategies involve the student in the design processes for monitoring progress or problems solutions for achieving those goals. The difference between successful students from unsuccessful students, it is often that successful students set goals, or expected outcomes (Zimmerman, 1989). Csikszentmihalyi (2013, p. 44) points out that anxiety occurs when the task, or expected outcomes involves a very high challenge, with a very low performer skills, whether the person is a student, a worker, or just any person (See Figure 2).

Figure 1: Conceptual Model of Impact of Attitude, Efforts, and Other Factors in Course Outcomes



Source: Authors design. This figure shows the relationship of effort and other factors in course outcomes, and the attitude components on effort.

Figure 2: Quality of Experience According to Challenge and Capacity Levels



Source: Authors design- Based on Csikszentmihalyi (1997, p. 31), this figure shows the relationship of Capability level and Challenge level that induce quality experiences in work, study, sports, artistic or other activities. The ideal path when designing learning activities is to prepare capabilities level of students in order to start from relaxation, then to induce a sense of control (self-esteem), and finally increase the challenge level to induce flow.

To avoid anxiety, challenge should increase incrementally, but according to the confidence and capability of the performer, and at the same rate. The flow state begins to be experienced when these two variables, challenge and capability, are above average and keep increasing in a balanced way. The state of maximum flow occurs when these two variables are located in extremely high levels. Regarding the impact of goals on improving students' attention and greater involvement, i.e., efforts, the author of the theory of flow has declared that "when the goals are clear, the feedback relevant, and challenges and skills are balanced, attention becomes focused and full strength" (Csikszentmihalyi, 1997, p. 31).

Desirability of Flow State

The flow state tends to occur when a person's skills are fully involved in overcoming a challenge that he or she may face. Optimal experiences usually involve a delicate balance between the capabilities we have to act and the opportunities available for action (Figure 2). If the challenges are too high, we are frustrated, worried and finally anxious. If the challenges are too low relative to our capabilities or skills, we feel relaxed and then bored. If we perceive challenges and skills have a low level, we are apathetic. Conversely, when we have to face a high level of challenges that involve the application of a high level of skills, we probably have a deep involvement. This is what separates the states of flow from the ordinary experiences. A climber will experience this state of flow when the mountain demands full force and concentration; a singer when the song calls for the full range of her or his vocal abilities; a surgeon, when the operation involves new procedures or require an unexpected variation. These experiences allow flow states that provide flashes of intense living against a matte background. Right and upper zone of Csikszentmihalyi model (Figure 1). A normal day, with no induced flow states, produces boredom and even frustration and anxiety (Csikszentmihalyi, 2013). A person who experiences a state of flow is completely focused, and engaged with extreme psychic energy. His or her mind does not leave any room for distracting thoughts or irrelevant feelings. In this case, self-consciousness disappears (rapture, or ar*rob*amiento in Spanish), but one feels stronger than normal. The sense of time is absent and hours seem like minutes. In extreme state of flow, one feels time is not happening (Csikszentmihalyi, 2013). When the whole being of a person expands into a fully functioning body and mind, anything you do is worthwhile by itself; living becomes its own justification. In this harmonic convergence of physical and mental energy, life finally takes his own sense (Frankl, 2006).

Flow states inducement, in oneself or in people with whom we have contact, is important in diverse areas: 1) In everyday life, because we improve the quality of life and well-being, also called *euphoria*, 2) In education, besides making it more enjoyable or pleasant, flow states impact intensity and duration of the student's attention favorably, 3) In work, it improves the quality of life at work, beneficial psychological states are experienced, and most likely, following the HR model of Hackman and Oldham (1976), flow could also increases job performance, 4) In cultural activities, such as arts, or in leisure and hobbies flow may boost creativity and performance. It shows up when a musician, for example, he/she wonders and enjoys bright performances in such a way as becoming ecstatic or in rapture, or experiencing euphoria.

The orientation towards competency approach, high involvement, meaningful learning and group collaboration, implies that the professor designs a working structure in which students organize and develop their work as part of a team or a group (Fink, 2004). In teamwork literature, a distinction between group and team is done by identified the interdependence of the members of the group with respect to the task. Thus, the greater the interdependence the greater the need for interaction between members, i.e. the closer the interaction, and they will be identified as a team (Fink, 2004, Salas, Rosen, Burke and Goodwin, 2009).

Related to this, the attaining of a common result, i.e., a collective product when pursued by the team is another relevant feature of teamwork. To walk this step from group to team, instructional strategy requires a strong emphasis on the learning and application of concepts, i.e., that the activities of the teams of students engage them in these aspects (Michaelsen and Knight, 2004). For this, the implementation of activities in each topic of the course program should be increasingly oriented from a simple approach to a more complicated level. This promotes learning and allows teams a great cohesion, a situation that can make them more productive for next steps (Birmingham and McCord, 2004). Behind the whole work, on one hand there is a highly meaningful learning experience because team members can provide more volume and/or a great diversity of inputs. On the other hand, this can be achieved as a remarkable development of the group by increasing the interaction between group members (Birmingham and McCord, 2004, Bonals, 2013).

In following this approach, the teaching of statistics, in our case, collaborative and teamwork applies from the basic concepts of learning and data generation, throughout its collection and processing, analysis and interpretation, done by students but coached by the professor. An example is to develop a small survey in class in reference to students opinions about usefulness, complexity, like/dislike, interest on the subject, and personal characteristics of students and environment; and then go through the full experience up to results interpretation, keeping in mind one or more hypotheses. With an increased confidence in this process and a feeling of purpose and quality control, students expand the sample interviewing schoolmates in other statistical classes.

Another example is the team's division of labor and competition when throwing (dropping) a "dart" to a "100" line level marked in green and 80 and 120 in red on a 1millimiter precision graph paper board, because one student drops the dart, a second student reads the result, and a third one registers results and input them at a PC. By the way, the "dart" is made of a pencil with a needle inserted in pencil eraser. Besides that, there is an in-focus projector connected to the PC and Excel applications developed for this purpose so the group can watch right away the normal curve that shows up when the full collection of data are processed and displayed. Then, it is the proper time to explain the normal curve full topic at class, now that they are relaxed, feeling that they have control and ready for higher understanding challenges, i.e., we are moving bottom up in right sides quadrants in Csikszentmihalyi's model (Figure 1). You may see this process via our DropBox link. https://www.dropbox.com/sh/emvwi5dg3mgg1ns/1oy5PScX6-

DATA AND METHODOLOGY

In this section, we explain the methodology, based in our teaching experience and Csikszentmihalyi's ideas, for conceptually define negative perceptions and operational levels found for them, and actions to overcome those negative perceptions about Statistics learning, through competency-based learning, teamwork and use of accessible communication and information technology. We also present the instruments and statistical methods used to collect and process data and ascertain the impact of efforts in course outcomes. The explanation of this is via the following tables. As we can see, in Table 1, we have listed negative perceptions, and we have proposed actions to revert the negativity of them. We include also some examples to do so.

Table 1: Negative Perceptions in Reference to Statistics, and Overcoming Actions and Examples

Perception to Change	Actions to Change Perception	Examples
Statistics is abstract.	Generate and analyze concrete real-life data.	Students measure their body weights, heights and calculate body mass indexes. Visualize used car prices as a function of car millage using an Excel scatter diagram. Each student analyzes a different car.
Statistics is not useful.	Scatter diagram of car prices versus millage from data published in students local area newspaper (www.avisosdeocasion.com)	Students learn how much to pay for a used car, today and in my city.
Statistics generates anxiety.	"Play with darts" and compete in-class teams to get as many 100s as possible. Try to get them close to the 100 mark ; as many as possible.	Generate the corresponding distribution curve for each team using Excel. Calculate and interpret average and variance, and percentage in 100 ± 10 interval. Check how close is each team to a bell-shaped normal distribution curve.
	Throw two dices and register sums resulting by teams.	Compare how close is each team outcome to a triangular distribution.
Other negative attitudes	As needed.	As needed.

This table lists in first column three of the most cited negative students perceptions in literature associated with Statistics learning effort. In second column, we annotate our suggestions to design learning activities to overcome the negativity of each perception, and some examples of those actions in column 3. Each student uploads his own example as learning evidence to DROPBOX and is graded by a professor assistant with a rubric.

In Table 2 and Table 3, we define the meaning of outcomes and efforts, since we will be using regression analysis methods to capture the impact of efforts in outcomes. This, as a first approach to a structural equation model that could be emerging, in the near future, from our conceptual schema depicted in Figure 1.

Table 2: Statistics course outcomes

Outcome Level	Meaning in Survey	Outcome Level Tag for Researchers Only
1	I did not meet my objective. For example, “my objective was to get a 100”, or “my objective is just to pass” or “get a good grade” but I did not achieve it.	Very low
2	I got my objective just partially or less than expected. For example, “I got a good grade in concepts but I just passed in problems section”.	Low
3	I just met my objective. For example, “I got almost what I was expecting”.	High
4	I exceeded my objective. For example, “I got a higher grade than expected”.	Very High

This table describes the meaning of each course outcome level, as a semantic scale. This scale is included in questionnaire. The third column shows a short tag for each level code. These tags are not shown to respondents so they may not be induced to read just the meaning of each level, and answer without a careful pondering.

Table 3: Student Efforts in Statistical Course

Effort Level	Meaning in Survey	Effort Level Tag for Researchers Only
1	My effort was minimum or scarce.	Very low
2	I made good effort but I did not take my effort forward when difficulties arose.	Low
3	I worked hard even when difficulties arose.	High
4	I followed all the recommendations made by my professor for a careful exam preparation. I surmounted any difficulty.	Very High

This table describes the meaning of each course effort level, as a semantic scale. This scale is included in questionnaire. The third column shows a short tag for each level code. These tags are not shown to respondents so they may not be induced to read just the meaning of each level, and answer without a careful pondering.

We also should keep in mind that in a real world job as in classroom activities, experiential activities must have the characteristics of sports teams: clear goals, joint tasks, timely feedback and recognition by group members to individual contribution to the achievements. In our case, a statistics teaching class, collaborative and teamwork applies, from data generation through their collection, processing, analysis and interpretation as experiential activities for students. Besides the example mentioned above, another example is to develop surveys in class and go through the experience of collecting information, capture, process, interpret and write results using information and communication software and classroom equipment, keeping in mind one or more hypotheses all the way.

RESULTS

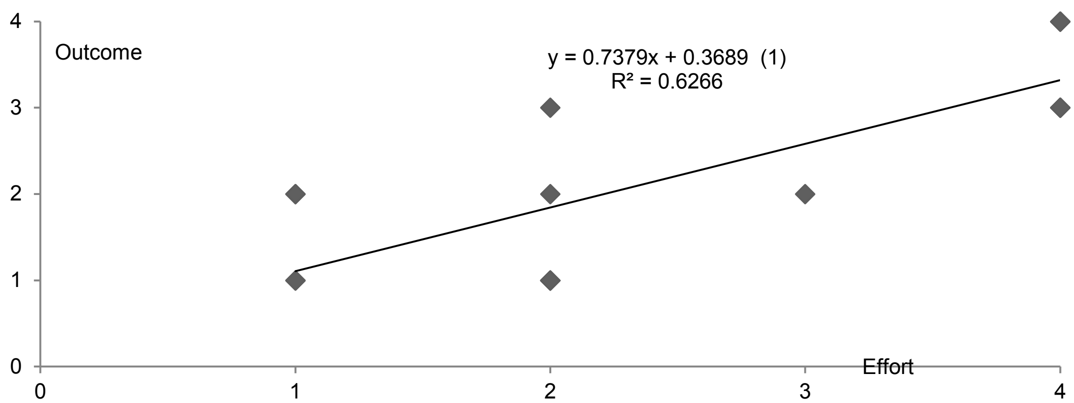
Shown next are the main findings when applying the methods we have suggested for teaching Statistics, explained in previous section. We have used codes from level 1 to 4 for a semantic scale; and in general, code 1 is for very low level, code 2 for low, 3 for high, and 4 for very high level. Results in reference to the usefulness of statistics are that 71% of the group or class said that it is substantial (Code 3) or very useful in her/his life (code 4). Considering the intensity of scale as metric, the hypothesis that *What is being learned is not useful* is rejected with $t = 11.09$ and p-value = 0.000, reaching the intervals limits between 2.8 and 3.6 at 95% confidence, which confirms the substantial usefulness deemed by students.

Regarding on how interesting or uninteresting is Statistics, as it is being taught, results are favorable to interesting side since 65% think it is considerably interesting (Code 3) and 29% as very interesting (code 4). Only 6% said it was just some interesting or nothing interesting at all. The hypothesis that *Statistics is not interesting* is rejected with $t = 16$ and p-value = 0.000, reaching the limits between 2.9 and 3.5 at 95% confidence, which confirms the inference that is considerably or high interesting.

In reference to complexity/simplicity, only 18% felt that the approach of the course was complex or very complex. Favoring simplicity 82% declared that it was simple (Code 1) and understandable (Code 2). The hypothesis that *The subject is complex* is rejected with t = 12.5 p-value = 0.000, reaching the limits between 1.5 and 2.2 at 95% confidence.

With respect to enjoyment of statistics as the course is conducted, students said that enjoyment was little, considerably or much, with percentages of 47%, 35% and 18% correspondingly. An important additional factor, which could influence results, is the method of study performed outside the classroom. The opinion that their method was not considerably good at all accounted for 18% of students; 24% of the class said that methods could be improved. Although 58% considered they have a good method anyway it could be better, they said. No student said she/he has a very good method. In reference to the impact of effort on course outcome that we have proposed in the conceptual model on Figure 1, we have found relevant and statistical significant impact as shown in Figure 3. One dot or point represents several cases.

Figure 3: Impact of Effort in Course Outcome



This figure shows the impact of effort on course outcomes, the trend line, the regression equation, the correlation and coefficient of determination, estimating that 63% of outcome variance is due to effort levels. One dot or point represents several cases.

The regression equation found is

$$Outcome = 3.69 + 0.738 * Effort \quad (1)$$
$$t = 5.02, p = 0.00,$$

The 95% confidence interval for R= 0.79 has a low limit of 54%, and 93% as an upper limit. Furthermore, as we can see in Figure 3, the confidence interval is substantial since it explains 63% of outcome. Outcome levels have assigned codes according to Table 2. The correlation coefficient between grades and outcomes was also considerable, 0.81. The 0.81 correlation coefficient between grades and outcomes shows that student's opinion on outcomes is consistent with grades.

CONCLUDING COMMENTS

Our research focus on proposing answers to crucial questions for improving statistics teaching. On one hand, there is the traditional perception that statistics is abstract, not useful, rigid, and that generates anxiety and negative attitudes especially in management science and socials students. On the other hand, there is the belief in society and its decision-makers that it should be a statistical literacy among its citizens for a better quality of life and better decisions-making processes.

In this exploratory research, we have tried to give the study of statistics an interesting approach, with meaningful learning, usefulness, and with an existential or experiential approach to understanding, more accessible and even fun or enjoyable. We have adopted a model to try to induce Csikszentmihalyi flow experiences among students.

With this new approach via a meaningful and competency-based learning, teamwork and using modern information technologies, we are getting encouraging and statistically significant results. Based on a questionnaire applied to students, with the new approach most of them (96%) consider Statistics interesting or very interesting, 82% deem that is understandable and even simple, and 53% that is enjoyable or very enjoyable, and 71% that Statistics is useful or very useful.

We have also proposed a conceptual model that connects attitudes, efforts and results. With information from these same students, we have found that 63 % of the variance in course outcomes is explained by efforts, not withstanding other matters as luck or other factors which we also will continue researching. The correlation between efforts and results is 0.79, with a 95 % confidence that this correlation parameter, in similar populations, may be located between 0.54 and 0.93.

We may think that a limitation of this study is that since it is a small sample (less than 30) results could be context dependent, but t-statistical-test are significant, so we could say that results are rather approach dependent. Another limitation is that outcomes do not depend exclusively on attitudes and efforts. We agree on this comment but a direction for future research is that of following the *Conceptual Model of Impact of Attitude, Efforts, and other factors in Course Outcomes* that we have designed, we could include research personal traits and habits, and to ascertain outcomes based on structural equations modeling.

APPENDIX

Context or Background of This Exploratory Research

The background or context of this exploratory research is a statistical analysis course taught in a school of business named FACPyA UANL, a university located in Monterrey, México (www.uanl.mx). This course corresponds to the semester January-June and is pursuing a competency-based education model. Some relevant details of this course are the following.

Course: Statistical Analysis in Management Process Course

Purpose: This course will help FACPYA student achieve correct applications of statistical analysis in the management process and its environment, supporting the general and specific professional competencies as stated in the UANL educational model.

Specific Competency Supported by This Course: This course supports the specific competence related to the optimal resource management of any organization through the responsible use of innovative technologies and processes in decision-making, performing advisory functions or specialized consulting to help create value and improve its competitive position.

Course Expected Outcomes: The student will identify the fundamental concepts of statistics, data description, through the effective management of data grouping and presentation techniques and analysis of measures of location and dispersion.

The student will demonstrate the understanding of concepts of probability, its rules, as well as some discrete and continuous distributions for the proper handling of the normal distribution as a tool for parameter estimation and hypothesis testing (mean, proportion, correlation methods and regression coefficients).

The student will demonstrate the understanding of concepts of correlation and regression between two variables applied to a specific problem.

The student will present a research project with information from a real company in which he/she applies the acquired knowledge in this course.

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BIOGRAPHY

Dr. Juan Rositas-Martínez has a BA in Economics UANL, MBA from Monterrey Institute of Technology (ITESM), Masters Degree Program in Econometrics UANL, Ph.D. in Management, FACPYA-UANL; he also took a Total Quality Management Seminar in Yokohama, Japan, and Seminars in Advanced Research at Georgia State University (Structural Equation Modeling) and Intercultural Competences in University of Arizona. In addition to the Spanish language, he also cultivates English, French and Mandarin. He has extensive experience as executive in various areas of FEMSA-Monterrey Industrial Group. He has been consultant in the private sector, independently and through ITESM, in the areas of labor compensation, and statistical quality management; in the public sector, through INAP (National Institute of Public Administration-México), and in the educational sector, independently. He has participated as a speaker at various national and international conferences and published articles, books and educational materials in his areas of specialty. He currently serves as professor and researcher, teaching in BA, Masters Programs and Doctoral Programs in CEDEEM - FACPYA Graduate Business School, UANL, with high quality recognition by the SEP-PNPC, participating in various committees to support educational management and as coordinator of a Faculty Research Team with acknowledgement of the Secretary of Public Education (SEP-México). His email: juan.rositas.mtz@hotmail.com

Dr. Joel Mendoza-Gómez has a BA in Economics, Universidad Autónoma de Nuevo León (UANL), MBA from UANL, Ph.D. in Management, Institute of Technology of Monterrey (ITESM). He currently serves as professor and researcher, and teaches in Masters' Programs and Doctoral Programs in CEDEEM - FACPYA Graduate Business School, UANL, with recognition by the SEP-PNPC. He also participates in various committees to support educational management and is Academic Coordinator of the MBA. He is a member of a Faculty Research Team with acknowledgement of the Secretary of Public Education (SEP-México). His current research interests focus on team effectiveness, group empowerment, shared mental models in work teams, work team competencies, and team-based learning. He has published articles, books chapters, and books in his areas of specialty. His e-mail is joel.mendoza@gmail.com.