Assessing Statistical Knowledge and Training Needs among Professionals in Ecuadorian Businesses: Implications for Education

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A study was conducted to assess the knowledge and frequency of use of statistics among professional roles from various businesses in different economic sectors in Ecuador. A tool was designed, based on the Guide for Evaluation and Instruction in Statistical Education and the Handbook of Statistical Methods by the National Institute of Standards and Technology, which made it possible to analyze the aptitudes of different professionals in relation to the use of statistics along their enterprises from different economic sectors. The data was collected by interviews and surveys to 246 people working in factories around the country. For instance, the results showed around 75% of the commerce sector requires to be more trained in reliability techniques, unfortunately the expertise of the majority of the sample shows that this part of the statistics it not a strength. The results also showed a lack of knowledge of statistical topics among the different professionals according to their professional roles. This study suggests that there is a need and an opportunity to increase education and training in the use of statistics within professional roles in several businesses around Ecuador.

Keywords: statistics training, statistics knowledge, economic sectors, use of statistics, professional roles

INTRODUCTION

National monetary evaluation, measured by gross domestic product (GDP), is an important measure of economic growth or decline of a country. Yearly increases in GDP requires highly trained professionals within different economic sectors in the collection, management and interpretation of data that allows them to make better business decisions. It is advantageous for business professionals to acquire and use

statistical analysis to summarize, interpret and act on evidence-based information (Cardenas Poblador & Jimenez Valderrama, 2014). Frequently, business managers in developing countries still lack the skills to produce, analyze and use the appropriate statistical methods required to support adequate decision making. In addition, many resources needed for increasing the GDP in developing countries are limited; therefore, good data management is important to help ensure that resources are used in the most effective way possible (Poverty, 2007).

The last two decades have seen a radical change in the dominant logic of the design of higher educational policies in universities of Ecuador directed toward higher levels of economic growth. Universities are encouraged to create a positive change in advanced statistical use and knowledge. These policy changes are based on the growth factors influencing society at large (Salgado_Arteaga & Cobos-Cali, 2018), which requires the development of programs designed to strengthen the production of goods and services throughout the business sector. In addition, universities are encouraged to develop opportunities within small communities to bring micro artisanal businesses toward the mainstream. As quantitative research skills become increasingly relevant for non-academic business professionals, an important objective of teaching programs at universities is to generate graduates who are interested in economic research and who are also capable of integrating science and practice into a set of skills, knowledge, and professional attitudes (Schuyten & Ferla, 2007).

Khan (2013) suggested that the use of statistics allowed an appropriate analysis of information from different perspectives, which improved decision making. That is to determine what can be inferred from data or statistical results and whether the justifications led to valid conclusions (Lestari et al., 2022). Implementation and validation of new statistical work tools can lead to new and better business strategies to increase effective and efficient performance (Donoso-Diaz et al., 2020).

Within a university setting, statistics education has the potential to help students to develop critical problem-solving skills in social contexts (Souza et al., 2020); however, the efforts of universities are not necessarily aligned with the requirements of economic sectors within a developing country. It could be inferred that educators prepare young people for a productive market around their perspectives, while many employers suffer a lack of skills of newly trained professionals. One possible explanation for the different perceptions is that employers and educators have different interpretations of the skills valued in the economic sectors; that is, there is a separation of criteria between these actors (Cunningham & Villaseñor, 2016). These factors have led universities to redesign their curricula in order to address global trends, both in the academic and business fields (Cardenas Poblador & Jimenez Valderrama, 2014). The redesign of the academic environment, including experiments and practices, have strengthened and improved the education of students around the needs of modern society (Li et al., 2011). Keh et al. (2016) explain how a constructivism theoretical framework might develop in an easy manner the strategies required to teach mathematics and relates science. The author explains how this way is effective to achieve news strategies. But the question here is which statistics knowledge are the most relevant for the different professional carrier?

One problem that it is possible to infer, in this point, is that the training in the statistics methods, is not aligned to the techniques required in the factories and business. This could be studied from two perspectives, the university curricular design (syllabus) and the requirements of the economic sector and their weakness. The study reported here is designed to analyze the frequency of knowledge and use of statistics by professionals in different business roles from different economic sectors within main cities in Ecuador, with the finality to create a method to obtain evidence to improve the education curriculum in a future.

Literature Review

Economic Sector

The economic progress of a nation involves the use of capital to enhance human productivity, create prosperity, and boost the overall national income. This process is accompanied by various social and cultural transformations. Therefore, a country's economic growth is influenced not solely by the quantity of labor and capital but also by institutional, cultural, educative and technological elements that dictate how labor and capital are employed (Massey et al., 2005).

Economic changes of a country is the result of its dynamics between production and consumption. Countries with higher economic growth generally have greater resources, which improves productivity and the standard of living of the population.

Presently, numerous organizations are leveraging data to enhance the quality of their strategic and operational choices. The practice of utilizing data for decision-making is not novel; in fact, since the introduction of data warehouse systems in the early 1990s, business entities have been storing and analyzing vast amounts of data. Nevertheless, the type of data accessible to most organizations is evolving, and these transformations introduce challenges in effectively handling the increasing volumes and complexity of data analysis (Daniel, 2015).

Statistics, both as a science and in practice, has contributed significantly to the decision-making process in businesses; and in government. Its importance is so great that practically all governments have internal departments or committees dedicated to carrying out statistical analyses (Ignácio, 2010). Therefore, one key role of statistics is in the planning and successful development of each productive sector of a nation (Khan, 2013). For this reason, this science has a critical role in the development of countries (Shangodoyin & Lasisi, 2011).

Statistics in higher education

Higher education institutions are currently functioning within a more intricate and competitive setting. They face mounting demands to adapt to changes on a national and global scale, including the necessity to boost student enrollment in specific fields, incorporate workplace-related skills into graduate attributes, and ensure that their educational programs maintain relevance at both national and global levels. The pressures are driven by economic, political, and social factors, making it essential for institutions to navigate these challenges effectively (Daniel, 2015).

Today, the rapid growth of publicly available data reinforces the need for public understanding of statistics and data interpretation. These skills are important for data-based decision making at individual-level and corporate level. However, statistics have been accused as a complex educational topic (Legaki & Hamari, 2020). This complexity causes undergraduates finding some difficulties in learning and understanding the courses if such complexity is conventionally studied using pencalculator, for that reason, lecturers should provide adequate opportunities for undergraduates to acquire the abilities in the classroom (Mairing, 2020).

However, the main objective of statistics education is to create adults who are proficient in statistical thinking and can use it effectively. Among all disciplines, statistics uniquely allows students to acquire the necessary knowledge in just one introductory course. It is in this introductory course that teachers hold the responsibility to either inspire or fail to motivate students in developing the essential statistical skills that will be valuable in both their professional and personal endeavors (Ramirez et al., 2012).

On the other hand, the advance of information technologies, and in general, the knowledge that society has gained, specifically in the area of the use of statistics, has increased greatly in the last 50 years. Statistics is one of the most used disciplines because of its holistic and universal support in the science of business (Barreto-Villanueva, 2012).

Studies have shown the importance of statistical knowledge in various professional fields. For example, Swarnalatha and Ramakrishna (2022) have shown the importance of the knowledge and use of statistics by health professionals' areas. Likewise, statistical knowledge is crucial for several careers such as biomedicine, psychology, sociology, commerce, business, engineering and education.

Reality in Ecuador

The historical evolution of the scientific-technological activity of Ecuador has led to different stages of transformation in the productive matrix that influenced the statistics of national production (Ronquillo & Ronquillo, 2017). However, the way of teaching statistics has not changed much over the years. Some researchers have tried to leave aside the traditional way of teaching statistics in order to adapt to the needs of constant change in the professional world. Related to this Cruz (2020) shows how collaborative learning can be used in the subject of statistics, with the aim of forming students with greater skills to understand data. In this sense, it is increasingly important to seek new ways to align the teaching of statistics with the professional reality of the country, since statistics plays a fundamental role in the improvement of a country's productive growth.

In this sense, Khan (2013) shows how statistics have left a successful mark in diverse areas of economic science. A clear example of this relates to the local agricultural sector, where, by using statistical techniques, evidence is provided that allows governmental policy to be extended beyond the simple analysis of tons produced per hectare (Bonilla Bolaños & Singaña Tapia, 2019). Another important productive sector in Ecuador that benefits from the use of statistics is in the textile industry. For example, it is now possible to know the relationship that exists between technology and

productivity, and thus determine how the production processes of companies in this sector make them increasingly effective, efficient and competitive (Ibujes Villacis & Benavides Pazmino, 2018). The importance of the use of statistics within the banking sectors is also well known, for example: Ignacio (2010)explains that using statistical techniques, analyzes were carried out on the influence of productive credits from public and private banks in certain economic sectors. In the industrial sector, statistical techniques are used to monitor and control the quality of products and processes.

Evidence suggests that there is a great advantage and need for the increased knowledge and use of statistical analysis in business sectors in general. However, there are very few studies that have been done to access the knowledge and use of statistical analysis in the business sectors of developing countries. The study presented here addresses this gap in knowledge.

METHOD

The study reported here was carried out using a survey given to a cohort of 384 business professionals (finit sample size) from different economic sectors of Ecuador, 246 belong to sectors of interest, the others are sectors with a low impact in the economy. The sample was balanced for each sector, the people who participated in the study were selected considering professionals who are in positions of leadership, management, administrative, or who have personnel under their charge.

A stratified sampling procedure was used along with a tool developed by the authors based on the Guide for Assessment and Instruction in Statistics Education (GAISE) (Carver et al., 2016) and the NIST-SEMATECH guide ((Natrella, 2010). The individuals who participated in the study had a mean age of 34 years (sd = 8.7 years) and a mean work experience of 9 years (sd = 8 years).

It is important to mention that the GAISE can be used as a macro scheme to create an educational evaluation around the statistics, as a validated method for the statistics teaching, while the NIST-SEMATECH could be used as a micro structure to identify requirements in the economic sectors from a technical and business point of view.

Before the survey was administered, the main economic sectors of Ecuador were identified. There are 21 productive sectors throughout the world according to the International Standard Industrial Classification ISIC 4.0. Using this classification, a Pareto analysis was carried out (Figure 1) in order to determine the most representative sectors in Ecuador. When considering the income generated by the corporate business fabric of Ecuador in 2019 (the year prior to the COVID-19 pandemic), six sectors accounted for more than 80% of this income: 1) commerce, 2) manufacturing industries, 3) agriculture-livestock-forestry-fishing, 4) transport and storage, 5) information and communication, and 6) construction.
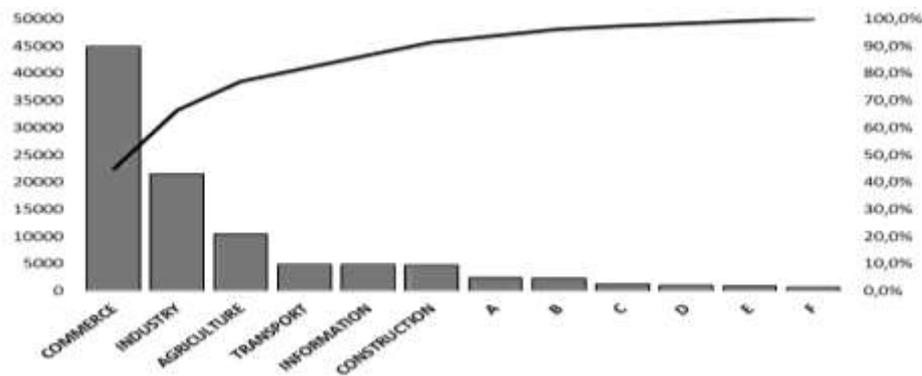
Figure 1
Pareto analysis for selection of productive sectors

A total of 384 observations were classified into the different sectors as shown in Figure 2.
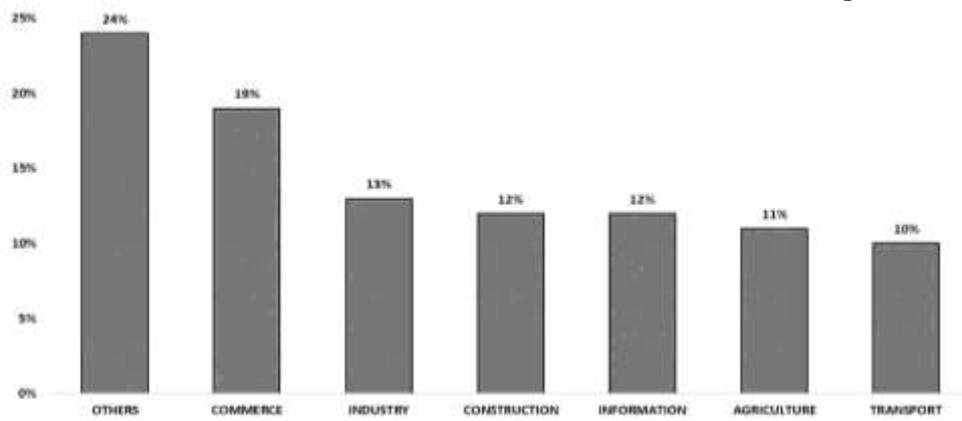
Figure 2
Sample stratification used in the study

Within the six productive sectors shown above, the following factors were investigated: a) an analysis of the frequency of use of statistics by professionals along with their perceived needs of statistics related to different data analyses in the given role into their businesses; b) the identity of the depth of the expertise and knowledge of these professionals regarding the use of statistics in their given role into their business. To achieve these objectives, a survey composed of eight questions was designed to measure the frequency of use and the expertise of the participants in different aspects of statistics, see Figure 3. Each participant had to choose the economic sector in which he/she identifies according to the role he/she plays in his/her business.

GAISE, developed by the American Statistical Association (ASA), was used (Franklin et al., 2007). GAISE groups statistical knowledge into sections based on competencies, which were the same groups outlined in the Handbook of Statistical Methods (Natrella, 2010). These were: identification of patterns, measurement instruments, data behavior, predictions, optimization, control, comparison and confidence.

The guide presents six main objectives: 1) the teaching of statistics-based thinking, which focuses on problem solving, decision making, and multivariate perspectives, 2) focused teaching on conceptual understanding, 3) the integration of real data around context and purpose, 4) to encourage active learning, 5) to use technology to explore concepts and analyze data, 6) to use monitoring and assessment to evaluate and improve student learning (Natrella, 2010)

To modify these objectives to better fit the study reported here, an evaluation tool was designed around the technical criteria of the NIST-SEMATECH guide, which are: explore, measure, characterize, model, improve, monitor, compare, and analyze reliability. A schematic of the tool is presented in Figure 3

Figure 3
Tool for evaluating use frequency and perception of expertise (knowledge) around the se of statistics in different given role in businesses

Note: For each question, a Likert scale between 0 and 5 was used, for the frequency of use where 0 = never; 5 = always, and for knowledge expertise the same scale where 0 = nothing; 5 = expert.

Data were obtained from different professionals within the main cities from Ecuador. An attempt was made to collect the information around a balanced sample according to the main productive sectors of the country. The sample number included 25 observations per sector corresponding to the number of participants who agreed to participate in the study in each

group. A classification analysis was performed using a decision tree algorithm and regression clustering, due to the subjective characteristics of the data. It is important to note that non-parametric classification trees are a supervised learning method used for classification and regression that make no assumptions about the distribution of the underlying data. The purpose is to classify data around grouping labels (Fletcher & Islam, 2019). For this grouping, a classification was made considering the following aspects: frequency: Likert scales from 0 to 2 is classified as "Use Little", from 3 to 5 "Use A Lot"; expertise: Likert scales from 0 to 2 is classified as "Knows Little", from 3 to 5 "Knows A Lot".

FINDINGS AND DISCUSSION

The tool was validated with regard to its design and construction using four categories; adequacy, clarity, consistency, relevancy; presented by Escobar and Cuervo (2008). The Kendall W was evaluated with an expert group of 8 people and its p-value is 0.00254. The reliability of answers scale was stablished using Cronbach's Alpha. The values obtained for the parts that measure the frequency of use and knowledge expertise were 0.88 and 0.92 respectively. Figure 4 shows the number of professionals and their frequency of use of statistical tools by the specified criteria (see Table 1). Figure 5 indicates the perception of knowledge according to the opinion of each individual.

Table 1
Symbols used in Figures 4 and 5

Symbol	F1 – E1	F2 – E2	F3 – E3	F4 – E4
Criteria	Explore	Measure	Characterize	To Model
Symbol	F5 – E5	F6 – E6	F7 – E7	F8 – E8
Criteria	Improve	Monitor	Compare	Reliability

Figures 4 and 5 show that individuals believe that they know little about statistical topics, and they consider that they use few statistics methods in their daily professional activities. This could be inferred as an educational abandonment around statistics and its uses, is probable that the statistics should be used higher during a making decision situation.
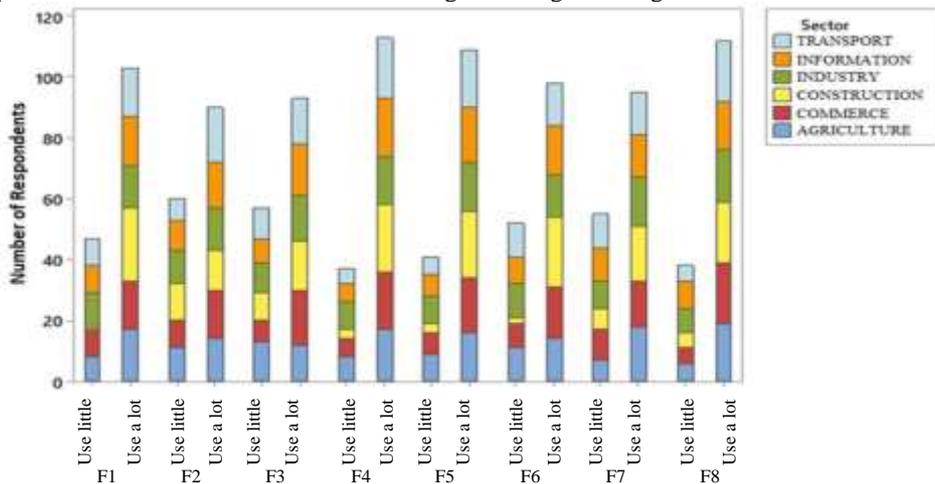
Figure 4
Amount of use (frequency) of each of the parts of the tool by sector
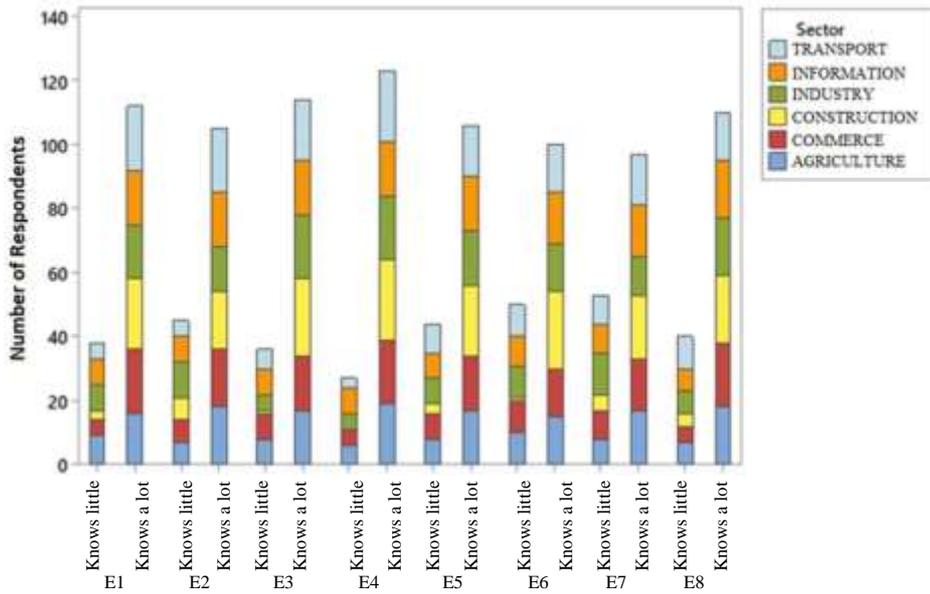
Figure 5
Amount of expertise of each of the parts of the tool by sector

Based on these results, an analysis was conducted using an event classification approach associated with decision trees. The objective was to identify the areas of application of statistics most used by the respondents along with their perception of expertise in the area. The resulting decision trees allowed the study of these application areas; some of which are shown in Figures 6 and 7 as examples.

Question 2: In the development of your profession, have you described and analyzed the behavior of data observed in a population?

Question 8: In the development of your profession, have you used techniques to guarantee the confidence of your results?
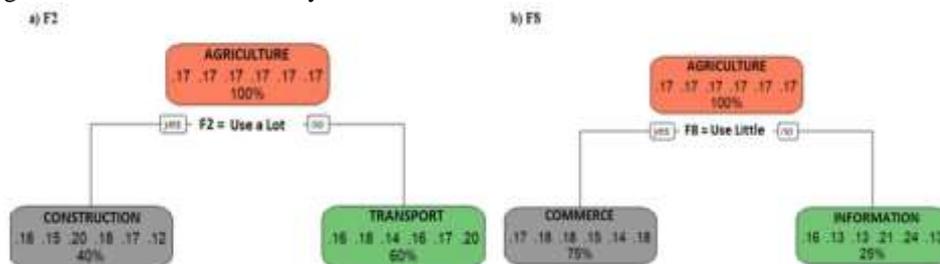
Figure 6
Classification trees for questions F2 and F8 for frequency of use sector
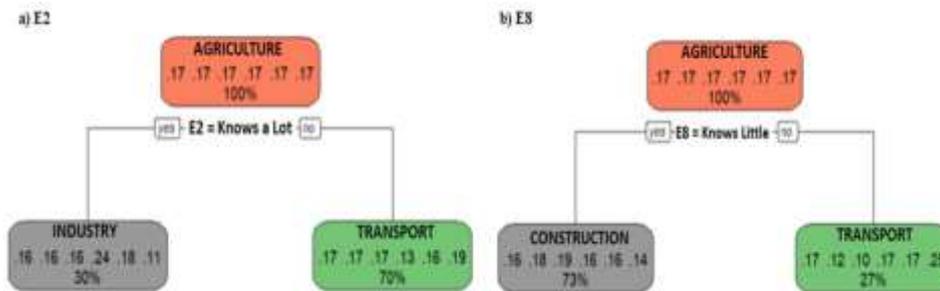
Figure 7
Classification trees for questions E2 and E8 for knowledge expertise

The decision trees in Figures 6 and 7 show the answers to each of the questions in the tool in a binary way in order to make a classification by assigning weights to each of the sectors. For each question, the classification algorithm selects an answer that will be evaluated in a binary way: branches to the left of each node represent "yes" answers and branches to the right indicate "no" answers. For example, Figure 6 a) analyzes the response to the question F2, "Use a Lot" regarding the use of scales and measurement instruments. The branch to the left shows the classification weights for different roles within each sector, with the Construction sector as the most important. Therefore, the roles at Construction sector have a great need for the F2 component of the tool whereas the roles at Transportation sector do not have as great a need for this component because it is located on the right branch of the tree.

It is important to note that the value of the weight must be greater than 0.17 to be able to classify a sector in any branch. Since there are 6 sectors, 0.17 is the value of the common weight for all; therefore, weights greater than 0.17 imply greater importance. This same analysis was performed for the knowledge expertise component.

With the information obtained through the classification weights of the trees, the following tables were designed as a summary of the results for all the questions of the tool (see Tables 2 and 3).

An analysis of Tables 2 and 3 highlight the fact that professionals belonging to the Commerce sector indicate that their roles have a significant need to know statistical tools related to patterns and trends (Table 2), but their knowledge on this aspect is scarce (Table 3). Additionally, it is also possible to identify parameters in which professionals have a lot of knowledge on a specific subject, but it is not widely used in their business roles, for example, with regard to question 8, "guaranteeing confidence of your results" in the Transport sector.

The results of the study reported here agree with the conclusions of Schuyten and Ferla (2007), who suggests that people who have the skills and willingness to be involved in the use of quantitative tools are more prepared and comfortable analyzing data. These competencies and skills are not only necessary in an information and evidence-based society, but are also necessary to bridge the gap between science and practice. Evidence suggests that when people within an economic sector take advantage of the value of

data analysis, people who work there have the capacity to make better decisions. However, this is only possible when data analyses allow the creation of relevant information within the business area, which is sustained through studies and statistical approaches. The identification and proper use of statistical skills will allow timely decisions to be made and remove the potential risks that surround any economic activity in a country.

Table 2
Summary of results for frequencies of use

Sectors	Evaluation of Statistics Frequency Aspects							
	Identify Patterns or Trends	Prepare, use scales, measuring instruments	Analyze data behaviors in a population	Approach reality and make predictions	Optimize	Monitor and control	Compare Information	Verify and ensure data reliability
Agriculture	○	✓	✓	✓	✓	✓	✗	✗
Commerce	✓	✗	✗	✗	○	✗	✓	✗
Construction	✗	✓	✗	✗	✗	✗	✗	✗
Industry	✓	✓	✓	✓	✓	✓	✗	✓
Information	✓	○	✗	○	○	○	✓	✓
Transport	✓	✗	✓	✗	○	✓	✓	✗

Note: symbols present in the table have the following interpretation: the green mark indicates that the professionals of a sector use a lot the specified statistical aspect; the red x indicates that this statistical aspect is not widely used by the different professionals and the yellow circle indicates that these statistical aspects may be used sporadically.

Table 3
Summary of results for knowledge expertise

Sectors	Evaluation of Statistics Frequency Aspects							
	Identify Patterns or Trends	Prepare, use scales, measuring instruments	Analyze data behaviors in a population	Approach reality and make predictions	Optimize	Monitor and control	Compare Information	Verify and ensure data reliability
Agriculture	✓	○	✓	✓	✓	✓	✗	○
Commerce	✗	○	✓	✓	✓	✓	○	✗
Construction	✗	○	✗	✗	✗	✗	✗	✗
Industry	✓	✓	✗	✓	✓	✓	✓	○
Information	✓	✓	✓	✓	✓	✓	○	○
Transport	✗	✗	○	✗	✓	✓	○	✓

Note: symbols present in the table have the following interpretation: the green mark indicates that the professionals of a sector know a lot about the specified statistical aspect; the red x indicates that this statistical aspect is not well known by the different professionals and the yellow circle indicates that these statistical aspects may be known sporadically.

This information show that it is necessary to initiate a change in the curricula around the statistics teaching. New techniques, like simulations, artificial intelligence, creative and contemporary curriculums are necessary to develop a new education process (Waluya et al., 2018).

For instance, this study compares a set of curriculums of the Ecuadorian universities and its commerce, administration, and similar careers, where usually the majority of graduate students work in the area of the commerce and business. It is necessary to mention that 12 curriculums of several universities in Ecuador were studied and the framework of their syllabus is similar to the showed in this section. According to the evaluation and the results obtained the students in this area should focus at least in these specific education areas of the statistics to accomplish the activities in the commerce sector in Ecuador: Analyze data behaviors in a population, Approach reality and make predictions, Optimization, Monitor and control. Unfortunately, the curriculums (see Table 4) shows that they focus on the area of Analyze data behaviors in a population leaving 75% without enough attention, so, it is necessary to create a change into the traditional curriculum.

Table 4

Example of comparison for the commerce area between the classical curriculum in Ecuador and the requirements obtained in this study

Macro Section Syllabus Commerce Sector	Relative Percentage of hours suggested by section	Classification according to Evaluation Method Requirement	Requirement form the business sector
Generalities	7 %	N / A	
Data Description	21 %	Analyze data behaviors in a population	Analyze data behaviors in a population
Probability	10 %	N / A	
Distributions	13 %	Identify Patterns or Trends	
Index	3 %	Compare Information	
Sampling	9 %	Prepare, use scales, measuring instruments	
Confidence Intervals	9 %	Monitor and Control	Monitor and Control
Hypothesis test - Errors	19 %	Analyze data behaviors in a population	Analyze data behaviors in a population
Regression and Correlation**	8 %	Approach reality and make predictions	Approach reality and make predictions
			Optimization

**This theme usually differs in the quantity of hours designated
N/A not apply

Table 4 reveals that not all the areas required by the commerce sector are being addressed within this framework. In fact, the areas that are focused on are not necessarily the ones required by the sector organizations. A similar perspective is presented by Wallin et al. (2014), who argue that the challenges of the business world demand successful companies to act proactively. This is why the fundamental challenge

addressed in a university-industry collaborative approach is to enable each organization to leverage knowledge, skills, and techniques that are currently limited to a single organization. Companies need to comprehend how to optimally utilize knowledge.

The curriculum has clear objectives and expected results. However, the approach to achieving these objectives typically follows a structure guided by books. At this point, this study presents evidence that the syllabus structure could be enhanced by aligning it with the voice of the business and considering academia's input. This result aligns with the viewpoints expressed by Radermacher and Walia (2013), where the authors suggest that there is literature-based evidence demonstrating the gap between industry and academia. In fact, the authors explain that several changes in the curriculum across diverse careers are necessary, as they are embedded in other organizations. Universities need to gain a deep understanding of the conditions in the industrial environment.

It is important to mention that, these results have been limited to the Ecuadorian context and focused in the main economic sectors, taking in count for instance the commerce sector.

CONCLUSION

This study identifies the statistical needs of the organizations, with evidence that will allow for future improvements in university curricular content, considering the opinions of the various stakeholders. The tool developed through GAISE and NIST enables the identification of areas where curriculum content is misaligned with organizational needs. In the Ecuadorian context, higher education is usually based on traditional and highly conceptual theories. Therefore, it is necessary to design or implement new approaches along study planification in order to create a flexible modern education. In other words, there is a need to redesign curricula to incorporate the flexibility of modern teaching.

From another point of view, there are evidence of a possible divergence in the curricula of the higher education in the Ecuadorian context when the business requirements are studied. For instance, in the commerce sector as an example, it is shown that there is statistical knowledge that is neglected or little studied, which require greater attention from universities. The results show that there are opportunities for improvement in the statistics teaching model in Ecuador. In light of this, universities could reallocate curricular hours and redesign their curricula to align with the genuine needs of the country's economic sector. This approach would foster a constructivist framework involving all stakeholders.

For future research, it is recommended to expand the sample size focusing on specific roles, and then contrast the results of their needs with the Ecuadorian university as a whole, the results obtained requires to be contrasted applying the same methodology to a different balanced sample.

From the educational point of view, it is required to generate a pilot test where the curricular structure is modified in a university house of study, in this way the necessary data could be obtained to measure the improvement and the impact suggested in this study. Finally, the methodology proposed here could be used as a quantitative basis for decision making regarding business, educational, and scientific needs, by considering

profile evaluation, as well as generating possible indications to initiate deeper scientific studies, among common business areas, educational levels, or curriculum analysis, among others.

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