Challenging the gender gap in STEM with Python and Data Science: case of the National Technical University de Costa Rica

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Abstract

In Costa Rica, there is an underrepresentation of women in STEM areas (ratio of 30-70), with the current rate of women's participation being lower than the Latin American average (45-55). This is a collaborative work between two Costa Rican state universities to empower female students and university professors in the area of data science. The Data Science Project for Biodiversity Conservation of the Technological Institute of Costa Rica (TEC) and National Technical University (NTU) carried out a capacity development project with an emphasis on biodiversity conservation through data science. This work was aimed at the Software Engineering community in the NTU to develop the capabilities of women in taking leadership positions in technology and research projects, thus helping to reduce the gender gap. The project admitted 35 women out of 72 applicants; of those, 13 students completed the requirements satisfactorily. The great successes in the execution were: inspiring, in the students, an interest in participating in data science projects applied to biodiversity conservation; the use of active teaching-learning methodologies that enhanced the development of skills in each student and motivated the participants to investigate and solve case studies, laboratories and projects; and finally, the transmission of the necessary knowledge so that they can transfer it to future generations for the benefit of society, moving towards a more inclusive and sustainable future.

Keywords

gender equality, data science, biodiversity, occupational qualifications, adult learning

1. Introduction

In the 21st century, gender equality is projected as a crucial and necessary objective in all organizations, especially in those areas related with science, technology, engineering, and mathematics (STEM). How to address this deep-rooted disparity, as well as empower women in fields where their representation is limited, is what this article presents through a project developed by the Technological Institute of Costa Rica (TEC) in collaboration with the National Technical University (NTU). An innovative project for female students and professors of the Software Engineering program at the diploma and bachelor's levels of the NTU, in which a group of women participate in a Python course with a focus on data science applied to the analysis of biodiversity data. The participants not only acquire technical and research skills through active methodologies such as research projects and case resolution, but they also become agents of change in their communities on conservation issues. The objective of the project is to train female computer science students and professors in areas of high public interest and labor demand to promote personal and socioeconomic growth of women in STEM, in order to reduce the gender gap.

This document is organized as follows: first, the background; the second section describes the methodology used in the project; the third section presents the results and discussion in detail; and

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finally, the conclusions and future work.

2. Background

Initiatives on gender gaps in education and work are developed in various areas, especially in 21st century universities, [1] where the transformation in the preponderance of the role of gender equality between women and men is taking place [2][3][4]. In the case of science, technology, engineering, and mathematics (STEM) disciplines [1], the underrepresentation of women in these careers and jobs is more marked than that of men [5][6][7].

On the one hand, the challenges faced by men include problems of retention in the educational system, linked to failure, and lack of motivation. On the other hand, even if they obtain notable results in school grades, women encounter obstacles when applying scientific and logical-mathematical knowledge [8], such as lack of confidence in their abilities, anxiety about the future and less flexible mentalities.

The root of such differences lies in stereotypes present from an early age [9]. Influencing socialization processes and affecting academic opportunities and careers. This trend is intensified in technical education and university graduation: despite an increase in the graduation of women in STEM, a concentration in specific areas is observed, with limited progress in disciplines such as engineering and computing, characterized by mathematical and programming content [10][7].

An example of this are the figures reflected in the labor market in our country [8]. There is still a persistence in the gender gap, especially in scientific-technological occupations: women represent 34.4%, below the national average of female labor participation (39.3%). In high-demand areas, such as Science and Technology (S&T) that often offer better-paid employment opportunities, the disparity is noticeable: men occupied 86.1% of the positions in 2021, which constitutes a difference of 72.2 percentage points with respect to women. At a national level, only 8.1% of the total number of employed people work in scientific-technological jobs: while men represent 65.6%, the proportion of working women is 34.4% [8].

It is urgent to reduce these inequalities through actions in education, proposing the interest of teaching staff, support in specific tasks and the creation of an environment that encourages diversity. It also highlights the importance of emotional health, especially for women, as a significant factor in academic results [8]. Additional research indicates that women who are more likely to develop STEM paths require a convergence of factors, such as early vocation, self-confidence, supportive environments, and role models throughout their career [10].

Despite an increase in the number of women enrolled in STEM fields in public universities between 2001 and 2021, challenges remain [8]. Access gaps, especially in male-dominated courses such as engineering and computing, continue to be notable [11]. In addition, female representation in leadership roles, such as executive management positions, is limited, as women occupy low percentages in these positions.

However, there has been a strong evolution in the participation of women, young people, and girls in spaces of greater equality of opportunity, although there is still a long way to go [8]. Gender equality is seen as a cross-cutting issue of social justice, with the intention of creating more inclusive societies with more sustainable economies.

Governmental and non-governmental organizations, as well as educational institutions, highlight the results regarding the gap in the participation of women in leadership positions, in equal contribution in scientific research, for example, in the generation of studies in artificial intelligence (AI), in the field of technology and engineering driven by the Fourth Industrial Revolution and in areas such as cybersecurity. In other words, sexism persists, so it is necessary to promote new, more inclusive and gender-sensitive spaces at a regional level to involve women and girls and develop initiatives that involve both, men, and women for reasonable equality. As indicated by the UN Sustainable Development Goal 5: “Gender equality is not only a fundamental human right, but it is one of the essential foundations for building a peaceful, prosperous and sustainable world.” [12].

2.1. Active methodologies

Active methodologies represent a pedagogical perspective that stimulates critical thinking and improves communication among university students [13]. As noted in studies, these strategies emphasize the active participation of students, using more dynamic tools such as collaborative problem solving and reflective dialogue that allow for deeper learning and thereby strengthens the understanding of the content [14].

It is clear that the development of thinking is gradually obtained, in the process of building knowledge. And one cannot expect that such knowledge is transmitted from "one mind to another" [15].

2.2. Data Science

Data science is an interdisciplinary field that combines statistics, artificial intelligence, mathematics, computer engineering, and domain-specific expertise to extract knowledge from data. That is, it focuses on the analysis and interpretation of large, complex data sets, with the goal of discovering patterns, relationships, and trends that enable informed decision making [16].

Data science has become a crucial research tool for in several areas, including biodiversity informatics, medicine, physics, astronomy, psychology, engineering, and management, to name a few. Data scientists support different areas of research to analyze large data sets, find patterns and trends in the data, and make predictions based on the results. For example, in biodiversity informatics, data scientists can help analyze large genetic data sets and find patterns that can be used to better understand gene function and their relationship to disease.

Data availability is increasing rapidly, so the potential for value creation through data science is growing every year. Yet most of the world can access such value only thanks to systems built by other people, usually by large technology companies. Better training of people in the country will allow a wider variety of problems to be solved, thus contributing to human development.

Data science is a rapidly growing field that is revolutionizing research, technological development, and innovation investigation system. The rate of adoption of data science-based technology is increasing in all countries of the world. As a result, the demand for qualified personnel in such areas is increasing without showing signs of slowing down. The country faces the great challenge of taking advantage of these opportunities and also addressing the significant underrepresentation of women in the workforce in this area since, in the face of all the national challenges, it is not possible to afford to underutilize all the talent available in women living in Costa Rica.

2.3. Female representation in computing careers in Costa Rica

Public universities, such as TEC and NTU, work within a framework of transparency, which is why it is easy to access public data on the profile of students entering and leaving each year. When talking about engineering majors in Costa Rica, it is common to hear that there is a significant difference in the number of female students compared to the number of male students. This raises the following question: How much of a numerical difference is there between women and men in computing at TEC and NTU?

Table 1
Proportion of first-year students' sex in the Computer Engineering program at TEC and NTU for enrollments from 2013 to 2019. Data retrieved from: https://www.tec.ac.cr/estudiantes-primer-ingreso and https://www.utn.ac.cr/area-de-investigacion.

Year	Enrolled students	Proportion of women (%)	Proportion of men (%)
2013	1851	35.12	64.88
2014	1696	34.85	65.15
2015	1757	35.06	64.94
2016	1901	27.67	72.33
2017	1554	33.59	66.41
2018	1831	32.28	67.72
2019	1923	31.10	68.90
	On average	**32.81**	**67.19**

(a) Technological Institute of Costa Rica (2013-2019)

Year	Enrolled students	Proportion of women (%)	Proportion of men (%)
2015	505	24.55	75.45
2016	364	28.57	71.43
2017	421	25.89	74.11
2018	457	28.01	71.99
2019	421	25.65	74.35
2020	420	32.62	67.38
2021	428	25.93	74.07
	On average	**27.32**	**72.68**

(b) National Technical University (2015-2021)

Table 2
Proportion by sex of students who graduated in computing from TEC and NTU in the 2013 – 2019 period. Data retrieved from: https://www.tec.ac.cr/graduados and https://www.utn.ac.cr/area-de-investigacion.

Year	Graduated students	Proportion of women (%)	Proportion of men (%)
2013	146	18.49	81.51
2014	173	23.12	76.88
2015	139	13.67	86.33
2016	160	16.88	83.13
2017	207	16.91	83.09
2018	220	15.91	84.09
2019	249	17.27	82.73

(a) Technological Institute of Costa Rica (2013-2019)

Year	Graduated students	Proportion of women (%)	Proportion of men (%)
2011 | 2015	276	28.99	71.01

(b) National Technical University (2011-2015)

Tables 1 and 2 show that on average for both universities there is an approximate ratio of 30-70 female representation, which, according to the Network of Science and Technology Indicators (RICYT), is much lower than the average margins in Latin America, which are approximately 45% women and 55% men. [17]

2.4. The Sustainable Development Goals (SDGs)

The UN 2030 Agenda for Sustainable Development sets out a framework of goals and targets to address a range of global challenges. Biodiversity and gender equality feature prominently in many of the Sustainable Development Goals (SDGs) and associated targets and contribute directly to human well-being and development priorities [12]. For example, Goal 5, Gender Equality and Women's Empowerment, states "Women play a key role in sustainable development through their role in education and the well-being of families and communities." Additionally, Goals 14 on Life Below Water and number 15 on Life on Land represent the planet and the protection of nature. Goal 14 focuses on the conservation and sustainable use of oceans and marine resources for sustainable development. Goal number 15, meanwhile, seeks to protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, reverse land degradation and halt biodiversity loss. Both goals are crucial to preserving biodiversity and natural resources, thus promoting a more sustainable future for all.

2.5. Importance of biodiversity

Biodiversity is crucial for human survival because of all the services provided by ecosystems; for example: oxygen production, drinking water provision, food production, climate and disease control, removal of pollutants and protection against disasters such as earthquakes, landslides, hurricanes, and floods. Although there is currently more awareness of its importance, efforts to conserve it by countries around the world are insufficient. This is demonstrated by the failure of the goals of the 2002 Earth Summit and the 2010 Aichi Targets led by the United Nations (UN). In the Fifth Global Outlook Report (2020), this global organization confirmed that biodiversity conservation goals have not yet been achieved [18] which is why at the last XV Conference of the Parties of the UN Framework Convention on Climate Change (COP15) of the Convention on Biological Diversity (2022), the new Kunming-Montréal Global Framework was adopted to safeguarding and sustainably using the biodiversity of the planet.

3. Methodology

To generate capacity building and empowerment of women in the region, the research team of the TEC Data Science for Biodiversity Conservation project proposed a pilot research project, the results of which are presented in this section. The objective of the project is to train women in computing in areas of high public interest to foster their personal growth and help reduce the gender gap in STEM careers. To achieve the project objective, the target audience was selected, and activities were planned, including the preparation of a Python course for data science, and course evaluation instruments, among other elements.

3.1. Origin of the course

It was considered beneficial to offer an Introduction to Python program since it is known as one of the most widely used programming languages today [19], In addition, it is also beneficial giving a first approach to data science to open up to the participants the possibility of participating in future projects and work in a field so recognized worldwide in recent years [20]. In this way, it was planned to motivate university women or graduates in STEM to get involved in the professional or research field in computing to promote and increase personal development, promote the advancement of the socioeconomic situation of women in the region and train seed generators to motivate a future generation of women in STEM.

3.2. Target audience

The course was aimed at female professors and students of the Software Engineering program at NTU, since, due to the nature of their curriculum, they do not use Python for their programming practices, and they are not offered any type of approach to the data science branch. To manage registrations for the course, a registration form and characterization of the target audience was designed using the *Google Forms* platform. To promote participation in the course, digital and physical invitations were published at the five different NTU campuses, namely, Alajuela, San Carlos, Atenas, Puntarenas, and Guanacaste. Likewise, several computer laboratories at the NTU in Alajuela were visited to spread the news of the course, discuss the initiative, and motivate the population.

3.3. Student Admission Process

A total of seventy-two people applied for the registration form; of these, 35 women who had passed the Programming III level of the third year of the Software Engineering degree program (Plan B05) at NTU were chosen. This requirement was established to ensure that the students had at least one year of programming experience. Thanks to the joint work done by both universities (TEC and NTU) and the registration form, a profile of the population interested in enrolling was created. Knowing the student population was key to designing the course according to the needs of the participants, since

it was taken into consideration that more than 50% of the students work and study at the same time, students are more confident in programming languages such as: C#, JAVA and SQL, and also, that most of them have less than 4 years of programming experience.

3.4. Aspects of the course

The course covers basic concepts of data science, which are taught using the Python language. The appropriate semantics and syntax for reading and writing in the language are practiced through the development of programmed tasks, practical laboratories, and research projects focused on biodiversity, due to the nature of the network in charge.

3.4.1. Organization

The planned course was taught virtually from September 28 to November 16, 2023, so that participants from all NTU locations could attend. It was decided to develop the course with a total duration of 36 hours: 16 hours of synchronous class spread over eight classes and 20 asynchronous hours to complete the established work and tasks. To manage the course, the decision was made to use *Google Classroom* because it is a free, easy-to-use tool and has full integration with an online Jupyter Notebook editor, such as *Google Colaboratory*, as well as with other Google documents. For virtual classes, *Zoom* platform, a tool widely known due to the 2020 pandemic caused by the SARS-CoV-2 virus (COVID-19) was used.

3.4.2. Evaluation

The course had a minimum passing grade of 70 out 100 and a required attendance of at least 75% of the synchronous lessons. The course evaluation consisted of three short tasks with a total value of 30% of the grade; two laboratories that add up to 40%; and a final research project of 30%, which required a deliverable programming, its respective documentation, and a final presentation.

3.4.3. Contents

The topics were planned to follow an intuitive order from the most basic Python to small examples of machine learning. The classes were divided as follows: Python fundamentals, introduction to data analysis; with an explanation of the Object Oriented Programming (OOP) paradigm for a better understanding of Python libraries such as Pandas and NumPy, introduction to the representation of geospatial data; with libraries such as *GeoPandas* used to work with *Geographic Information Systems (GIS)*, and an introduction to machine learning; through the use of examples.

3.4.4. Course methodology

It was decided to use a theoretical-practical strategy to focus the course on active and collaborative learning among the participants. This involved opening weekly spaces for solving exercises, that is, each week they were assigned a task where they could put into practice the knowledge learned in class. Likewise, consideration was given to developing the students' research capacity to apply the concepts seen in the course in the final project.

4. Analysis of results and discussion

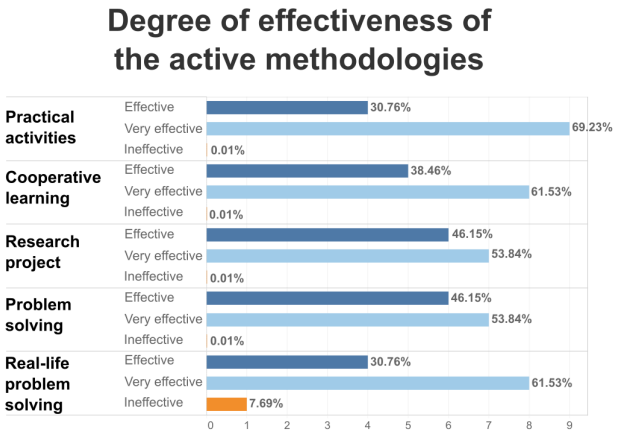
The course was completed by thirteen of the selected women, of which 90% are between 20 and 30 years old, 50.8% belong to the Alajuela Campus of the NTU and the rest are divided into other campuses of the University. Regarding the academic level, 53.8% are in the process of finishing high school and 38.5% have a bachelor's degree or higher. An exploratory study was conducted with them through a course evaluation form; where we sought to know the interest of a group of students and professors of the NTU in actively participating in research on data science topics and research applied to biodiversity

conservation to promote sustainable and inclusive development in the country. The instruments designed during the execution of the project contain sections that allow us to answer the research questions of the project:

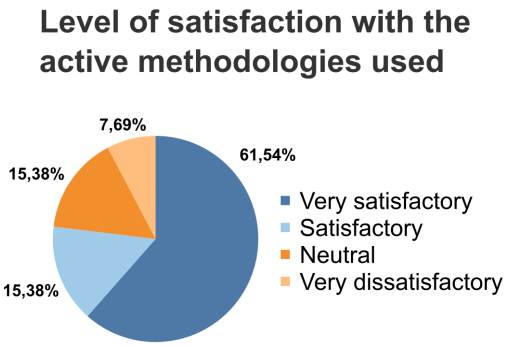
- The implementation of active methodologies in teaching and learning.
- The course content: quality, usefulness, and relevance.
- The level of interest of the group in data science topics.
- The level of interest in data science topics applied to biodiversity conservation.
- The opinion of the participants on the impact that training women in data science has on the socioeconomic development of the country.
- The general satisfaction of the students.

4.1. Active teaching and learning methodologies used during the course.

Thanks to the course evaluation form, the opinion of the students regarding the inclusion of active methodologies in the course and the degree of effectiveness with which they rate them can be found out. Seeing positive opinions in this regard gives indications of a satisfactorily conducted work, where it is established, and which techniques were effective during the execution of the classes.



(a) Degree of effectiveness of the active methodologies.



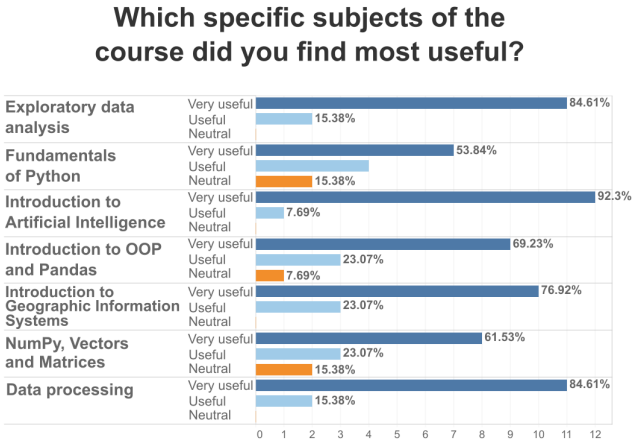
(b) Degree of satisfaction with the active methodologies.

Figure 1: Opinion on the inclusion of active methodologies used during the course.

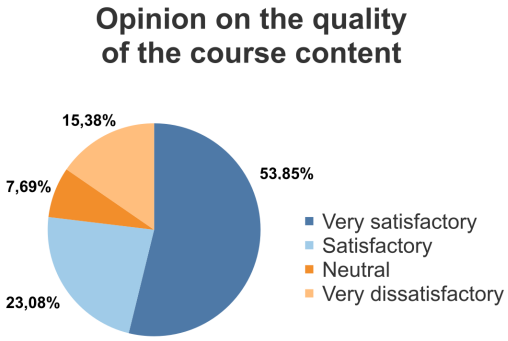
As can be seen in *Figure 1b*, 92.3% of the students have a positive opinion, according to the Likert scale [21], about the active methodologies used, which is a great indication that the work conducted was well received by the student population. In addition, it can be noted from Figure 1a that "Practical activities" is the highest rated methodology, which shows that leaving weekly work assignments is well received as a positive methodological aspect.

4.2. Course content: quality, usefulness, and relevance.

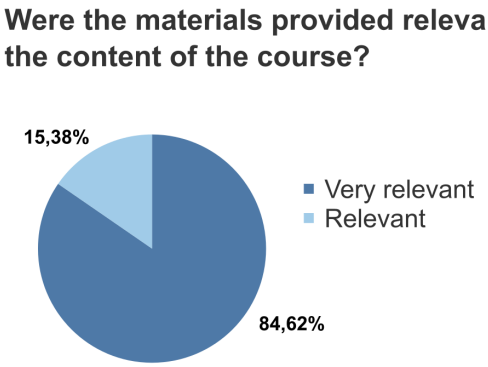
An important aspect of this study is to assess the degree of satisfaction of the student population with respect to the course content. The evaluation form shows results regarding the perceived quality, usefulness, and relevance of the course materials. These metrics are important to assess the current strengths and weaknesses, in order to analyze more specifically how to improve a next iteration of the classes.



(a) Degree of usefulness of the course topics.



(b) Degree of satisfaction with the quality of the course content.



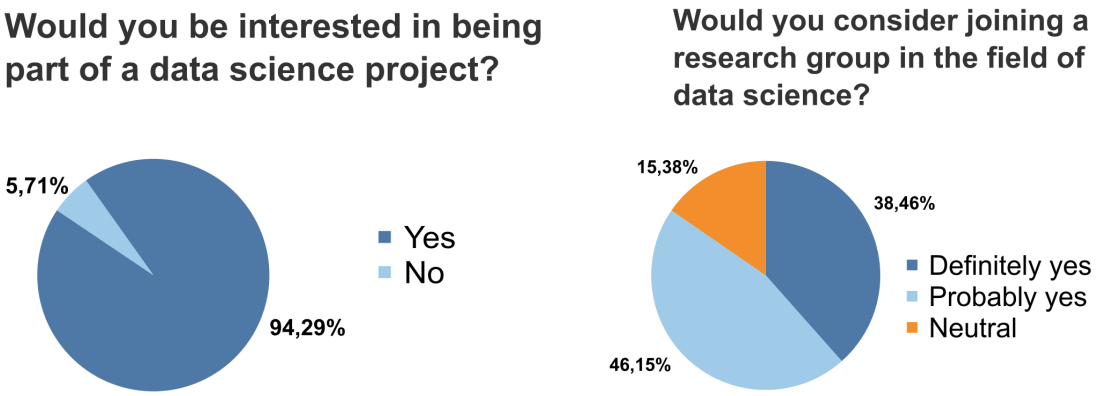
(c) Degree of relevance of the course content.

Figure 2: Opinion on the course content.

Again, in *Figure 2b*, it can be seen that 84.6% of the students have a positive opinion on the content taught, which is a valuable indicator that initiates a suitable selection of class topics. Note in Figure 2a that the topic "Introduction to Artificial Intelligence" is the topic of greatest interest, and as in Figure 2c, it presents 100% positive evaluations. This interest in artificial intelligence is of utmost importance for developing new courses in the future and knowing that the topics are found to be highly relevant is a great support for conducting a new iteration of the course.

4.3. Group interest level in data science topics.

The results obtained in the question *"Would you be interested in being part of a Data Science project?"* are shown in Figure 3a and are part of the first form completed (the course registration form), where it is evident that there is a great interest in the student community in being part of projects related to this field, however, there is a small part of the population that refrains from participating.



(a) Interest in participating in Data Science projects prior to the course.

(b) Interest in participating in Data Science projects after the course.

Figure 3: Comparison of interest in participating in data science projects before and after the course.

In contrast to the results of the question *"Would you consider joining a research group in the field of data science¿'* shown in *Figure 3b* and part of the study conducted with students who completed the course, it can be seen that now 100% of the responses are positive. Although the population that responded is smaller, it is expected that by offering learning opportunities on these topics, the interest of the student population in participating will improve.

4.4. Level of interest in data science topics applied to biodiversity conservation.

Figure 4 answers the question *"Would you consider being part of a research group on Data Science topics applied to biodiversity conservation?"*. It can be assumed that the general interest of the participants is high since all the answers are positive and the students do consider being part of a research group in which they can continue studying and increase their knowledge in data science applied to the area of biodiversity.

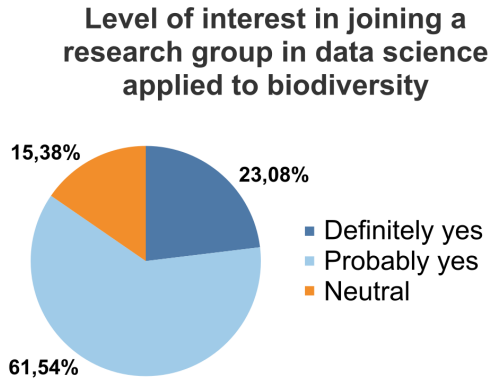


Figure 4: Degree of interest in belonging to biodiversity research groups

This result is taken as a success because the biodiversity approach present in the course awakens an interest in the students to continue researching in that area.

4.5. The opinion of the participants on the impact that training women in data science has on the development of the country.

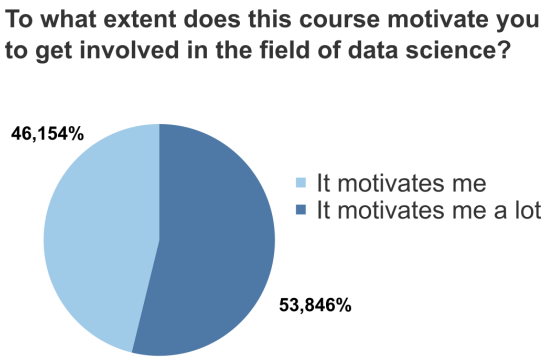
This topic was answered with a short form, similar to an interview, in which four students who graduated from the course answered the question *"What impact do you think a greater female representation in high academic and professional positions could have, at a socioeconomic, family and/or work level?"* in a free manner. The following are the opinions of the students in question:

- "It contributes to greater participation of women in the productive sector, regardless of the industry in which they wish to work. The beneficiary is the woman who allows herself to develop skills that make her feel important."
- "Inspiration for more generations, I believe that the perspective of girls greatly complements the work of boys, inclusion generates diversity and with diversity you can go further."
- "A huge impact, we are very capable, resilient and organized and that can contribute significantly and positively to any environment in which we are."
- "The truth is that it seems very good to me, since female participation is important, because it motivates more women to want to study software engineering."

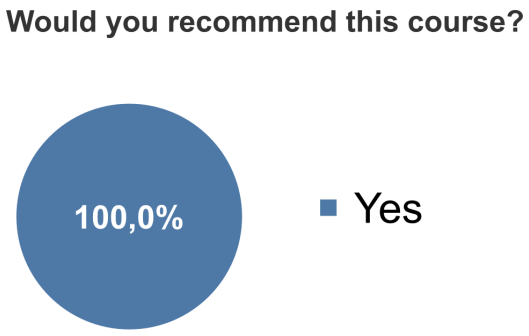
In summary, it can be seen that the students interviewed agree that a greater representation of women in positions of power generates self-confidence. In turn, this inspires future generations to achieve the same and, in this way, move towards a better economy for their families and the country.

4.6. General satisfaction of the students

One of the objectives of the evaluation form was to measure the impact that attending the course had on them, to find out if the course motivated them and if they would recommend it to other people. These results can be seen in the following figure:



(a) Degree of motivation to engage in data science.



(b) Course recommendation rates.

Figure 5: Opinion on the overall impact of the course.

As shown in *Figure 5*, the course positively influenced the students and fulfilled the objective of awakening in them an interest in learning and becoming more involved with data science and biodiversity.

5. Conclusions

Among the conclusions of the project, the following can be highlighted:

- There is interest among the students and the participating professors of the Software Engineering (ISW) program participating in the course, regarding data science and its application. The proposal

was strengthened, having been directed towards the conservation of biodiversity, since the NTU is committed to sustainable development, and closely related to the SDGs. Making clear the importance of continuing to promote extracurricular activities with the Python Workshop for Women, which not only promote the participation of young women in these fields, but also guarantee gender equality and equal access to education, especially in STEM disciplines.

- Active methodologies in education have proven to be highly effective in the teaching-learning process. Their benefits include greater retention of information, development of skills appropriate to the context of each participant, greater motivation and commitment of students, and better preparation to face the challenges of projects executed at a professional level. The course participants experienced these benefits and evaluated the results of their application as satisfactory. The course was planned to give greater emphasis to practical activities, which was highly evaluated by the participants.
- Regarding the usefulness and relevance of the materials, 100% of the course participants considered that the content taught was relevant or truly relevant. One element worth highlighting is the interest of the participants in the topic of artificial intelligence, which leaves open the possibility of continuing to teach advanced topics in AI to female students and professors at NTU in the future.
- The interest in data science projects from 100% of the participants enrolled at the beginning of the course is high, which makes it evident that it is worth developing capacities in the subject in the student population of the NTU in general and establishing research groups in data science applied to various areas, including the subject of data analysis applied to biodiversity conservation.
- Participants believe that training women in data science benefits the country by increasing their participation in the productive sector and promoting inclusion and diversity. They believe that this inspires future generations and highlights the unique skills that women bring, which can have a significant positive impact on the work environment as it generates diversity of ideas and solutions. In addition, they recognize the importance of female participation in motivating future generations of women to study software engineering careers.
- It is worth highlighting the participation of the TEC Computer Engineering students who taught the course since they demonstrated their leadership skills, highlighted their sense of sharing and encouraged the participation of women as well as generated solidarity among students. Interuniversity work strengthens the ties between both public institutions, for the benefit of society, moving towards a more inclusive and sustainable future.
- Finally, it is important to evaluate the reasons why not all participants completed the course; these elements can be an important input in the gender analysis required prior to future planning of capacity development activities.

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