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Data Analysis and Simulation, a Playful Experience Generated from the Tropical Dry Forest

Anamaria Franco-Leyva and Oscar Moreno-Torres
Civil Engineering Faculty
Engineering Faculty
Universidad Cooperativa de Colombia
Santa Marta, Colombia
anam.franco@campusucc.edu.co, oscar.morenot@campusucc.edu.co

Ivan Gil-Ruiz
INBACTER S.A.S
Escuelas de ciencias aplicadas e ingeniería
Universidad EAFIT
Medellín, Colombia
igilruiz@gmail.com

Abstract

The advancement of modeling and simulation strategies is pivotal for digital engineering across all engineering domains, offering foresight into potential challenges and preventing cost overruns. Conversely, without acknowledging planetary boundaries and taking decisive steps toward sustainable development, ensuring the preservation of life and leveraging Industry 4.0 advancements becomes uncertain. Hence, it's imperative for engineering education to incorporate a curriculum attuned to the environmental crisis.

Validation and simulation techniques have become integral components of engineering education since 2020. Recognizing the necessity to enhance programming skills geared towards statistical analysis, particularly among Civil Engineering students, initiatives have been introduced. These include leveraging tools like MATLAB, integrating online mini courses, engaging in the Python Fundamentals Marathon, and fostering collaborative project environments among students from various engineering disciplines.

The activity provided students with a comprehensive and immersive experience that went beyond mere theoretical learning. It allowed them to actively engage in every stage of the data collection process, from initial observation to the compilation of relevant information. Through hands-on participation, students gained a deeper understanding of the intricacies involved in gathering empirical data and the importance of accuracy in this process.

Moreover, the integration of this activity with the tropical dry forest environment surrounding Cerro Seco added another layer of significance. As students conducted their research amidst this natural setting, they were able to appreciate firsthand the delicate balance of ecosystems and the potential consequences of human intervention. The juxtaposition of the pristine natural environment with the adjacent City Quarry provided a stark contrast, underscoring the importance of environmental conservation and sustainable practices.

Keywords
Education in engineering, simulations, data analysis, integral formation

1. Introduction

Within the challenges posed by Industry 4.0, it is underscored that the development of strategies and tools for modeling and simulation stands as a cornerstone for digital engineering, with broad applicability across all engineering domains. This significance is accentuated by the virtual representation of products and processes, facilitating proactive identification of potential challenges and mitigation of production overruns, material waste, and resource depletion. Furthermore, the burgeoning presence of Big Data necessitates engineers' adeptness in data analysis, trend recognition, decision-making, and process optimization. Conversely, the absence of acknowledgment of planetary limits, alongside inadequate efforts towards sustainable development, jeopardizes both life preservation and the effective utilization of Industry 4.0 advancements. Thus, engineering education mandates a curriculum tailored to the prevailing environmental crisis, fostering proactive responses to contemporary imperatives.

Planetary boundaries, also known as planetary limits, constitute a conceptual framework evaluating the status of nine fundamental processes crucial for Earth system stability. These boundaries delineate thresholds for processes that, if surpassed, could jeopardize the planet's habitability. Key among these limits are: 1. Climate change, evidenced by a 1.1°C temperature rise since the Industrial Revolution, leading to extreme climatic events like droughts and floods. 2. Ocean acidification, impacting marine life and ecosystems through alterations in ocean pH. 3. Ozone hole depletion, with potential severe health and environmental repercussions. 4. Nitrogen and phosphorus cycle disruption, driven by excessive fertilizer use and pollution, disrupting natural cycles. 5. Water resource overexploitation, threatening freshwater availability. 6. Deforestation and land use changes, causing habitat alteration and biodiversity loss. 7. Biodiversity loss, marked by species extinction and ecosystem degradation. 8. Atmospheric particulate pollution, negatively affecting health and climate. 9. Chemical pollution, posing environmental and health hazards. Continuous monitoring and adherence to these boundaries are imperative for ensuring a sustainable future for our planet. (Goddek et al. 2019).

The Validation and Simulation Techniques course has been integrated as a cross-disciplinary component within the Engineering curriculum. Since 2020, it has been implemented with students from Civil Engineering, Electronic Engineering, and more recently, Environmental Engineering. Through this implementation, it has been observed that students in Civil Engineering face specific challenges, particularly in programming. This is attributed to their professional context, resulting in low usability of programming software, notably Matlab, deficiencies in statistical data analysis, and limited application of course content in both academic and professional settings.

For this reason, a Pedagogical Practice was designed towards Cerro Seco Natural Training, a thematic park born to conserve the tropical dry forest through sports and recreational activities, aiming to demonstrate that the hills bordering the city of Santa Marta are more than just quarries and illegal constructions but sources of progress and sustainable development.

The field trip allowed for the integration of knowledge addressed in the course related to statistical components, data analysis, and programming in Matlab through a playful strategy that enabled students to engage in the following time-capturing activities:

- Trunk race and "Take the Seed out of the Owl"
- Palenqueras races and "Build a Native Nursery"

The purpose of the playful activities was to consolidate stochastic arrival processes so that students could identify the type of process addressed, in this case, Queueing Theory (Ayyub and Richard H. McCuen 2011). Furthermore, it required the application of descriptive statistics for initial data analysis, assessment of distribution types associated with these events through hypothesis testing for distributions, generation of random numbers, and assessment of data validity for simulations, among others. The challenge of the activity included physical performance and ultimately data analysis and simulation in Matlab.

On the other hand, considering the dimensions of being, the contribution towards holistic education revolved around the complement provided by the Cerro Seco thematic park. Among the activities developed was a one-kilometer walk through the tropical dry forest and an environmental talk aimed at raising awareness about the importance of preserving the Tropical Dry Forest, as it is one of the most threatened ecosystems in Colombia, with agricultural and infrastructural activities being among the main causes of degradation (Ministerio de Ambiente y Desarrollo Sostenible n.d.). Additionally, the strategic location of the park, nestled within the tropical dry forest and adjacent to a quarry,

promotes the contrast between economic activities related to ecotourism versus soil exploitation for aggregate and stone extraction.

Another contribution to holistic education was the development of social construction of knowledge, recognition of others, and the creation of social fabric, camaraderie, and friendship that were fostered. Interaction in randomly assigned workgroups, with whom students may have never previously interacted, occurred, and play, fun, and physical performance activities complemented intellectual endeavors. The creation of this type of activity stemmed from the need to generate a healthy environment to strengthen interpersonal bonds and develop tools that enhance mental health. In 2023, the suicide attempt rate in the city of Santa Marta increased by 30% compared to the previous year(Greace Alejandra Avila Mellizo Subdirector Diana Marcela Walteros Acero et al. n.d.).

1.1. Objective

The main scope of this research is to assess the effectiveness of incorporating validation and simulation techniques, alongside environmental education, into engineering curriculum to enhance students' understanding of sustainable development principles and their ability to apply these principles in real-world scenarios. By immersing students in hands-on activities that integrate data collection, simulation development, and environmental analysis, this research aims to foster a holistic approach to engineering education that not only equips students with technical skills but also cultivates their awareness of environmental challenges and the importance of sustainable practices. Through this approach, the research seeks to bridge the gap between theoretical knowledge and practical application, preparing engineering students to address complex challenges while prioritizing environmental stewardship and contributing to the advancement of Industry 4.0 in a sustainable manner.

2. Literature Review

Throughout history, humanity has been recognized as inherently social beings. Influential philosophers such as Aristotle have emphasized the role of the environment in shaping human behavior. Emile Durkheim, a prominent figure in sociology, contends that education stands as a paramount tool for fostering social cohesion within society (United Nations, 2008). His seminal work notably illustrates "the distinctiveness of social interactions from individual psyches, emphasizing their amalgamation into a collective entity with unique characteristics, thus establishing it as the focal point of sociological inquiry" (Mendieta y Nuñez 1979).

The evolution of education and pedagogy, along with the reciprocal relationship between pedagogical practices and society, has been marked by numerous points of convergence and disagreement. Nonetheless, each society determines the educational system to be instilled in individuals. Moreover, the education provided within a specific temporal and spatial context is influenced by various levels of social stratification.

In his work "In Praise of Difficulty and Other Essays" (Estanislao Zuleta 2020), Estanislao Zuleta presents a profound analysis of the prevalent trend towards ease and convenience in contemporary society. Zuleta delves into how this inclination towards simplicity shapes our values, perspectives, and ambitions, impacting not only personal development but also societal norms. However, juxtaposed against this prevailing culture, Zuleta underscores the inherent value of adversity as a catalyst for human growth and fulfillment across various spheres of life. He argues that grappling with challenges and surmounting obstacles not only fosters resilience and self-discovery but also enhances our academic, professional, and personal journeys. Ultimately, Zuleta's discourse prompts readers to contemplate the pivotal role of difficulty in shaping individual character and fostering societal resilience.

“Emotional Intelligence” by Daniel Goleman (Goleman 2010) explores the profound impact of emotions on our everyday existence. The book elucidates key insights into the workings of the emotional brain, highlighting its evolutionary significance in facilitating survival and adaptation. Goleman elucidates how the emotional system, housed within the limbic system, can operate autonomously from rational cognition, governed by the neocortex. He emphasizes the crucial role of self-control in managing emotional impulses, underscoring its significance in fostering resilience and emotional regulation. Moving beyond the mechanics of emotions, Goleman delves into the essence of emotional intelligence, contending that it surpasses intellectual prowess in determining life success. Central to this concept are core competencies such as motivation, persistence, self-discipline, mood management, and empathy, which collectively shape one’s ability to navigate life’s complexities. Moreover, Goleman elucidates the profound interplay between emotions and various facets of human experience, including the immune system and interpersonal dynamics, underscoring the far-reaching implications of emotional intelligence. By applying emotional intelligence

to diverse domains such as leadership, sales, and personal relationships, individuals can enhance their effectiveness and forge deeper connections with others. Goleman highlights the formative role of childhood in emotional development, emphasizing its pivotal importance as a window of opportunity for nurturing emotional competencies. In essence, "Emotional Intelligence" underscores the transformative power of understanding and harnessing emotions, portraying it as a cornerstone of success and well-being in life.

The Critical Educational Model with a Competency Approach at the Universidad Cooperativa de Colombia (UCC) is deeply rooted in critical theory and is dedicated to fostering quality education. Central to this model are its foundational principles, which include engagement with critical theory and a steadfast commitment to delivering high-quality education. One of the core tenets of the model is the emphasis on developing generic competencies in every higher education student, underscoring the importance of a well-rounded skill set in today's rapidly evolving landscape. Moreover, the model is characterized by its personalized approach, which prioritizes the individual's unique characteristics and needs, steering away from a one-size-fits-all approach to education. Additionally, the model is underpinned by an emancipatory ethos, aiming to empower individuals through education and enabling them to critically engage with their surroundings.

In its practical application, the model emphasizes the significance of competencies in leadership and interpersonal relationships, recognizing their pivotal role in navigating professional and social spheres effectively. Furthermore, the model highlights the critical importance of emotional development, particularly during childhood, in shaping individuals' overall well-being and readiness to confront life's challenges. Ultimately, the model's overarching goal is to provide a pragmatic and impactful educational experience that equips graduates with the requisite skills and competencies to thrive in today's dynamic world.

3. Methods

To conduct our research, we will begin by thoroughly analyzing the data obtained from each competition state. For each state, we will determine the type of distribution that best fits the data. This will involve selecting appropriate statistical methods and significance levels (Alpha) while justifying the choice of variable type for each state. Following this analysis, we will proceed to calculate the parameters of the distribution for each activity within the competition. This step is crucial for understanding the underlying characteristics of the data and will provide valuable insights into the variability of the process across different activities.

Once the data analysis is complete, we will move on to the simulation phase. Using the inverse transform method, we will simulate the process by generating random numbers. These numbers will undergo rigorous testing to ensure both uniformity and independence, validating their suitability for simulation purposes. With validated random numbers in hand, we will then proceed to simulate 100 data points for the variable under consideration. Additionally, we will calculate confidence intervals for the simulated data, providing a measure of the uncertainty associated with our simulations.

In parallel with the simulation, we will delve into queue theory to gain insights into the queue length or waiting line and the waiting time in the queue for the process. This will help us better understand the dynamics of the competition states and how they affect overall performance. Finally, we will calculate the length of replicas for the process, providing a comprehensive overview of the replication length and its implications for the competition.

By following this systematic approach, we aim to gain a deeper understanding of the competition states and their underlying processes. Through data analysis, simulation, and queue theory, we will uncover valuable insights that will contribute to a more comprehensive understanding of the competition dynamics and inform decision-making processes moving forward.

4. Data Collection

In the context of research or analysis, data collection refers to the process of gathering relevant information for a specific study. Here are some key considerations regarding data collection:

The choice of data collection methodology is crucial. It can include surveys, interviews, observations, experiments, document analysis, etc. Each method has its advantages and disadvantages. For instance, surveys are useful for quickly obtaining a large amount of data, but they may be biased by participants' responses. Instruments are the tools used to

collect data. These can be questionnaires, measurement scales, measuring devices, etc. It's important to design valid and reliable instruments to ensure the quality of the collected data.

The sample is the group of people or elements to be studied. Selecting a representative sample is crucial for generalizing the results to a broader population. Before collecting data from participants, informed consent must be obtained. This involves explaining the purpose of the study and any potential risks. During collection, responses, observations, or measurements are recorded according to the chosen method. Ethical and privacy guidelines must be followed to protect participants' confidentiality.

After collecting data, its quality is verified, and errors or outliers are removed. Data cleaning is essential to ensure reliable results. In summary, data collection is a critical step in the present document. The quality of the data directly affects the validity and reliability of the results obtained.

5. Results and Discussion

The Figure 1 illustrates a box plot representation, where the vertical axis denotes "GRADE" ranging from 1 to 5, and the horizontal axis represents "Semester" spanning from "2020-1" to "2023-2B". Each point on the horizontal axis corresponds to a box plot displaying the grade distribution for the respective semester. These box plots encapsulate the interquartile range of the data, with a central line denoting the median. Outliers are depicted as individual points lying beyond the "whiskers" extending from each box. This visual depiction offers a succinct overview of grade distribution dynamics across different semesters, facilitating a straightforward comparison of grade dispersion and central tendency over time.

Drawing insights from the provided figure, a comparative analysis between the earlier years (2020-1) and the latter years (2023-2B) of grade distribution is conducted. While the median grade remains relatively stable throughout the observed period, there is a discernible increase in grade dispersion in the later years, as evidenced by the extended "whiskers" of the box plots. This phenomenon implies heightened variability in student performance in recent semesters. In conclusion, while median grades exhibit consistency, the amplified grade dispersion suggests a greater divergence in student achievement. It is imperative to delve into the underlying factors driving this variability and devise strategies to uphold assessment consistency and equity. The recent increase in statistical dispersion can be attributed to students' enhanced empathy towards their peers, fostering a collaborative learning process aimed at achieving the minimum competencies required to pass the course. This shift towards collaborative learning signifies a departure from traditional individualistic approaches, as students actively engage with and support each other in attaining essential skills and knowledge. As a result, the widening dispersion of academic outcomes reflects not only variations in individual learning styles and abilities but also the collective efforts towards mutual understanding and skill development among peers. This trend underscores the importance of fostering a supportive and inclusive learning environment that encourages collaboration and empathy among students, ultimately contributing to more equitable academic outcomes and holistic skill development.

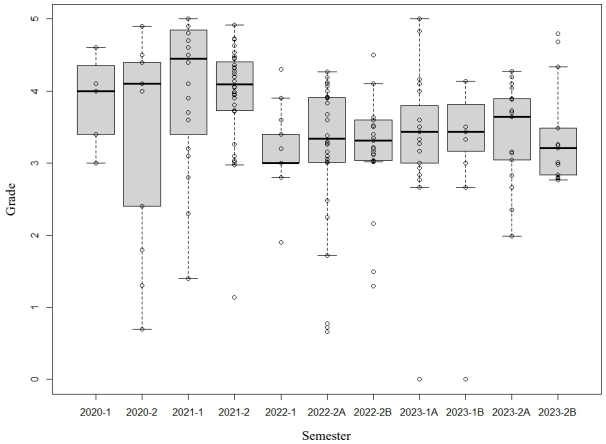

Figure 1. Employed population with SGRL and Employed population without SGRL

Table 1 provides a comprehensive examination of the data, revealing a decline in median scores from 2021-1 to 2022-3. Post hoc analysis further indicates that treatments sharing the same letters are not statistically different, thus emphasizing similarities in performance among specific groups. These findings underscore the potential influence of various factors, including changes in pedagogical approaches, teaching quality, or student demographics, on academic outcomes.

In conclusion, continuous monitoring and analysis of this data are essential for enhancing educational quality and ensuring consistent outcomes over time. By discerning trends and comprehending the underlying factors impacting academic performance, educators can implement targeted interventions to bolster student success and promote ongoing improvements in educational practices.

Table 2. Employed population with SGRL and Employed population without SGRL

Post Hoc Analysis

t-Student: 1.971007
Alpha : 0.05
Groups according to probability of treatment differences and alpha level.

Treatments with the same letter are not significantly different.

	NOTA	groups
2021-1	157.70000	a
2021-2	156.46875	a
2020-1	143.50000	ab
2020-2	133.53846	ab
2023-2A	108.00000	bc
2023-1B	102.27273	bc
2023-1A	101.96429	bc
2022-2A	98.75000	bc
2022-2B	95.59615	bc
2023-2B	93.76923	bc
2022-1	83.11667	c

Figure 2 presents a comparative analysis of attendance trends between earlier years and recent semesters, revealing discernible patterns that offer insights into student engagement dynamics. Initially, a notable stability in relative attendance is evident, characterized by the consistent presence of the largest segment, Relational 1 (25.6%), across the study period. This constancy suggests that students maintain a consistent level of engagement, reflecting a sustained interest in educational activities. However, juxtaposed with this stability is a noticeable increase in attendance variability, as evidenced by the expanded dispersion of attendance rates. While segments like Mult structural 2 (1.3%) and Mult structural 3 (7.0%) show reduced participation levels, others such as Abstract 1 (16.3%) and Abstract 2 (6.2%) demonstrate relative stability. Furthermore, a distinct decline in attendance is observed within the Uni structural 1 segment (6.6%), highlighting an area of concern warranting further investigation.

Subsequently, a comprehensive exploration of the implications arising from the observed attendance trends is imperative. While the consistency in relative attendance implies sustained student engagement, a deeper examination of the underlying factors driving this phenomenon is essential. Considerations such as the effectiveness of teaching methodologies, the relevance of course content, and the accessibility of resources may significantly influence students' enduring interest and participation levels. Additionally, investigating the demographic composition within the Relational 1 segment holds promise in identifying specific student cohorts exhibiting consistently high engagement, thereby facilitating the development of tailored interventions to support broader student success initiatives.

On the contrary, the heightened variability in attendance, particularly the decline in unique attendance within the Uni structural 1 segment, necessitates careful scrutiny. This decline may arise from diverse factors, including scheduling conflicts, competing academic commitments, or challenges related to inclusivity and accessibility. Identifying the root causes of this decline is essential for devising effective strategies to mitigate it. Potential interventions such as offering flexible scheduling options, enhancing academic support services, or implementing targeted initiatives to boost student motivation and engagement emerge as viable approaches to address this issue. Furthermore, a holistic examination of the broader institutional context and external influences impacting attendance patterns is indispensable. Factors such as institutional policy changes or external socio-economic dynamics may exert significant effects on students' attendance behaviors. By adopting a comprehensive approach to attendance trend analysis and considering the multifaceted factors influencing student behavior, educators and institutions can formulate robust strategies to foster consistent attendance and cultivate a supportive learning environment conducive to student success.

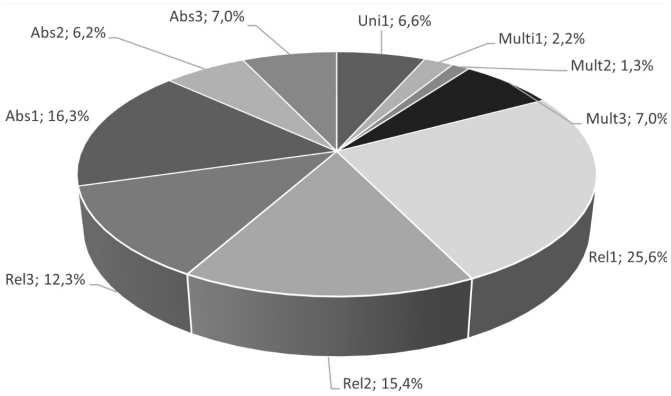

Figure 2. Employed population with SGRL and Employed population without SGRL

6. Conclusion

The present study underscores the pivotal role of modeling and simulation strategies in digital engineering across diverse domains, offering insights into potential challenges and aiding in cost management. However, the realization of Industry 4.0 advancements remains uncertain without addressing planetary boundaries and embracing sustainable development. Therefore, engineering education must adapt to the environmental crisis by integrating sustainability-focused curricula.

Validation and simulation techniques have become integral to engineering education, particularly in enhancing programming skills among Civil Engineering students. Initiatives such as leveraging MATLAB, online mini-courses, and collaborative projects have been introduced to address these challenges. The incorporation of hands-on activities, such as data collection in the Cerro Seco Natural Training park, provided students with immersive experiences beyond theoretical learning, fostering a deeper understanding of empirical data collection processes and environmental conservation principles.

Moreover, the integration of environmental education with technical training has further enriched students' learning experiences. Through activities in the tropical dry forest environment, students gained insights into the delicate balance of ecosystems and the importance of sustainable practices. This holistic approach not only enhances technical skills but also instills a sense of environmental stewardship, preparing engineering students to address complex challenges while prioritizing sustainability. By bridging the gap between theoretical knowledge and practical application, this approach contributes to the advancement of Industry 4.0 in a sustainable manner and cultivates socially responsible engineers equipped to tackle global challenges.

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Biographies

Anamaria de los Angeles Franco-Leyva Is full professor at the Universidad Cooperativa de Colombia. South America; member of the IEOM Society. She obtained her bachelor's degree in industrial Engineer from university of Magdalena and she earned her Master degree in Engineering at Eafit University. She won a scholarship to study about *G.sepium* plant and She tested its interaction with different microorganisms. She has been teaching Statistics and Simulations techniques since 2019 and she taught classes on safety and health at work especially in Construction sector. She has 4 years of experience working in Quality especially in Health, safety and health at work and 6 years in university Education Quality.

Ivan D. Gil-Ruiz, received as Process Engineering in 2012 from EAFIT University, Medellin-Colombia; Magister in Engineering in 2016 from EAFIT University. He is a plant manager and researcher of fermentative processes at INBACTER S.A.S, a company dedicated to the development of bioinoculants for agricultural uses based at biotechnologies developments. Additionally, he works as a professor of subjects of statistics and design of experiments, heat transfer, design in process engineering and Project 1, at EAFIT University.

Oscar Moreno-Torres, received the Bs. Eng in Civil Engineering in 1996 from Universidad Nacional de Colombia, Sede Bogota; Magister in Civil Engineering in 2000 from Universidad de Los Andes, and PhD in Civil Engineering from Universidad Nacional de Colombia, Sede Manizales in 2024. He is a Lecturer professor in Universidad Cooperativa de Colombia. His research interests include: Geotechnical earthquake engineering, modeling and forecasting in site response analysis; and slope stability analysis using neural network optimization.