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Journal High School

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Knowledge Area

The works must be unpublished and refer to topics of Higher education curricular standards, higher education training fields, higher education curricular frameworks, higher education curricular parameters and other topics related to Humanities and Behavioral Sciences.

Presentation of Content

In the first article we present *Analysis of the trend of emotional disorders in new university students*, by GRAJEDA-ROSADO, Ruth María, DIAZ-VEGA, Maria Eugenia, COUTIÑO-CLEMENTE, Asunción and HUERTA-ARIZMENDI, Guadalupe, with assignment at the Universidad Veracruz, as a second article we present *Predicting academic performance grades of control student using a LSTM neural network*, by TORRES-RAMÍREZ, Dulce Esperanza, JIMÉNEZ-GONZÁLEZ, Fernando C., HERRERA-OGAZ, José Alberto and MENDOZA-PÉREZ, Miguel Ángel, with adscription in the Universidad Tecnológica de Ciudad Juárez, as third article we present *Planned and impulsive buying habits and their relationship to life satisfaction in the staff of a higher education institution*, by GALAVIZ–ZAMORA, Marisol, MURILLO-FÉLIX, Cecilia Aurora, AMARILLAS-IBARRA, Priscilia Rossel and QUIROZ-CAMPAS, Celia Yaneth, with adscription at the Instituto Tecnológico de Sonora, as fourth article we present *Improvement of the production scheduling for the casting line in a manufacturing company*, by ACOSTA-QUINTANA, María Paz Guadalupe, BUENO-SOLANO, Alfredo, LAGARDA-LAEYVA, Ernesto Alonso and VEGA-TELLES, Ernesto Alonso, with adscription in the Instituto Tecnológico de Sonora.

Content

Article **Journal High School**
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Analysis of the trend of emotional disorders in new university students

Análisis de la tendencia de los trastornos emocionales en los universitarios de nuevo ingreso

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Abstract

In the search to support the students who enter the university, from the psycho-pedagogical point, this article highlights and analyses the results obtained from the institutional tool for consulting and collecting information on the admission profile (SCOPI) of the Universidad Veracruzana, which allows making appropriate decisions for personalized academic support programs (tutorials) at the beginning of the student's academic life. The research focuses on analysing two variables: Stress-Anxiety and Depression. A quantitative and descriptive methodology allows for examining the behaviour trend of these two variables covering a period of 8 years (2015 to 2022). As a result, an increase in the affirmation by young people of admission to presenting these disorders is obtained, seeing themselves aggrieved during the sanitary quarantine of COVID-19. In addition, the data express that the students of the economic-administrative area are the ones whom most claim to have these psychopathies.

Emotional disorders, University students, Information tools, COVID-19

Resumen

En la búsqueda para apoyar a los alumnos que ingresan a la universidad, desde el punto psicopedagógico; el presente articulo resalta y analiza los resultados arrojados de la herramienta institucional de consulta y recopilación de información del perfil de ingreso (SCOPI) de la Universidad Veracruzana, la cual permite tomar decisiones apropiadas para los programas de acompañamiento personalizado académico (tutorías) en el inicio de la vida académica del estudiante. La investigación se enfoca en analizar dos variables: Estrés-Ansiedad y Depresión. Mediante una metodología cuantitativa y descriptiva que permita examinar la tendencia del comportamiento de estas dos variables abarcando un periodo de 8 años (2015 al 2022). Se obtiene como resultado un alza en la afirmación por parte de los jóvenes de ingreso en presentar estos trastornos, viéndose agraviado durante la cuarentena sanitaria del COVID-19, además los datos expresan que los alumnos del área económico administrativas, son los que más aseveran poseer estas psicopatías

Trastornos Emocionales, Universitarios, Herramientas de información, COVID-19

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Introduction

The human body is a perfect work of engineering, a machine calibrated to maintain balance in its internal functions through the joint and interrelated work of some systems, such as the nervous system, whose task is to send signals to other systems of the organism for its functioning, the circulatory who is in charge of transporting blood with oxygen and nutrients to all the cells of the organism and conducting cellular waste to the lungs and the endocrine system that produces hormones or secretions supplied in the blood to manage bodily functions within the metabolism, sexual organs and tissues (UJAEN, 2022) other equally relevant systems are the digestive and immune systems. This set of systems works as an organized whole in a dependent and interdependent way to achieve its vital purpose, health. Within each system, multiple biological, psychological, and neurological processes are developed that make it possible for everyone to adapt to their social environment and develop intellectually and psychologically (Ramayo & General, 2017). A characteristic aspect of the human body is the synchronization of the production and functioning of each of the processes that occur within each system and organ and thus contribute to maintaining vital homeostasis.

The individual from birth is immersed in a social context where he learns to communicate and establish relationships with his environment. It does this through complex cognitive processes, which allow anticipation, development of attention, impulse control, self-regulation, mental flexibility, use of feedback, planning, organization, discrimination of strategies to solve problems, and monitoring (Anderson, 2008; Bausela-Herreras, 2014). The complexity of these mental abilities highlights their vital importance in regulating the individual's behaviour in different life scenarios.

Cognitive processes are classified into essential and superior. The basic ones are sensation, perception, attention, and memory; these are essential for the development of the superior ones; such as thought, attention, language, and intelligence; relevant in the teaching-learning process within the development of skills and competence necessary to achieve good academic performance.

School performance *"is the result of the complex world that surrounds the student: individual qualities (aptitudes, abilities, personality...), their social and family environment, their school reality (type of educational center, relationships with teachers and peers, teaching methods...)"* Op. cit (Morales et al., 1999 p.58). Another successful axiom is that of Montero, Villalobos, and Valverde (2007), where performance covers aspects such as teacher-student interaction, institutional, pedagogical, social, psychological, demographic, and not, limiting as an analytical product of an aptitude. Meanwhile, Isaza and Henao (2011) define it as a cause-effect training process in the participation of an educational situation versus the abilities of the educated. Becoming an indicator proportional to the level of learning and achievement of established objectives (Basto-Ramayo, 2017; Coello & Cachón, 2017).

Implication of emotional disorders in academic performance

The university student, as a biopsychosocial being and during his school career, can be altered in some or all dimensions, the emotional part being the most vulnerable and rarely identified, having physical, psychological, and behavioural manifestations (de León & Flores, 2018).

The disorders mentioned above that impact academic performance usually present with physical symptoms (fatigue), psychological (indecision, lack of concentration, distraction), and behaviourally (isolation, apathy, absenteeism, and increased drug interference (Suárez-Montes & Díaz-Subieta, 2015).

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The most frequent disorders during this university stage are stress, anxiety, and depression, which are generally not taken seriously and are confused with a stage of adolescent development, significantly altering their academic performance.

Stress

Due to its importance in the 21st century, stress is classified by the World Health Organization (WHO) as suffering from the *"set of physiological reactions that prepares the body for action"* Op. cit (Torrades, S., 2007, p. 105), The Royal Academy Española adds that it is caused by overwhelming situations that cause 2natural reactions in the human body, psychosomatic. For 50 years (Epstein, 1972), the definition of a state of physiological imbalance in the organism with unpleasant emotional and cognitive components was coined. Nowadays, it is studied for the effects it produces in the different psychological and social aspects and the behavior of the human being. His statistics indicate that in society, around 25% of the world's population suffers from it, which is considered a psychological health problem (Farkas, 2002; Valadez, 1997).

Pillou (2017) explains that it consists of a set of reactions that the organism undergoes when it undergoes radical changes. Our body reacts to what it identifies as aggression or pressure, so each person defends himself differently, and according to the traumatizing experience they have experienced. In general, stress is a consequence of the tension caused by unresolved personal conflicts.

The types of stress can be divided into positive (eustress) and negative (distress); the first is the natural process of adaptation that consists of acute activation of the senses and reflexes for a short period to deal with a situation—exceptional threat or other types that requires more effort. Positive stress causes a satisfactory sensation after having performed a complicated task for the individual; the second exceeds the homeostasis potential and causes fatigue, irritability, anxiety, or anger (Barrio, García, Ruiz, & Arce, 2006).

According to its duration, stress is divided into three; a) acute, typical human response to the demands and pressures of the recent past with the near future; b) episodic acute, which occurs when acute stress is frequent, generally caused by a large number of responsibilities, resulting in a reaction uncontrolled, emotional and irritable (Avila, 2014) and; c) chronic, constant state of alarm, where the individual does not envision the appropriate solution to a situation, coming from long or endless periods of demands and pressure, where in some cases it is camouflaged with previous traumatic experiences (Orlandini, 2012).

School or academic stress

They are the psycho-pedagogical disorders that students suffer due to pressure from physical, emotional, interrelational, or environmental factors, which cause poor school performance, low competitiveness, and poor metacognitive ability to relate what they have learned with their reality, affecting their relationships, with peers and academics (Martínez-Díaz & Díaz-Gómez, 2009).

This type of stress is classified as systematic with an adaptive character because the student is subordinated to constant demands that, in his assessment, are considered stressful (input); When these inputs create an imbalance, generating symptoms, the person affected to restore the balance reacts by creating coping actions, outputs (Barraza, 2006). According to several authors Castillo, Walker, & Castillo, 2015; Pulido, et al. 2011), the student environment is one of the most studied and prone to present situations of this type because they affect performance in an obvious way, the student population is a vulnerable group prone to particularly stressful periods since as the student progresses in their studies, stress increases and reaches the highest levels when they are in the upper level.

Some events that trigger stress in students are the transition from secondary to university level, competitiveness, academic demands, and study habits acquired in the previous stages of the educational system, which are not always conducive to a good adaptation of the student to the new training facility (Herrera, Rodriguez, & Valverde, 2010).

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It has been found that the most stressful moments in academic life are the entry into the first course of the degree and the time immediately before the exams (Léon-Rubio, 1992; Chacón, Rodríguez, & Tamayo, 2017). According to several authors (Bittar, 2008; Chacón-Centeno, Rodriguez-Feliciano, & Tamayo-Jimenes, 2018), the ability to manage stressors depends on the individual's personality, in other words, on how he perceives and interprets the events that cause stress; said conclusion derives from the very opposite responses among people, while some feel exhausted, overwhelmed and consumed, others feel stimulated, animated and excited.

Anxiety

The Diagnostic and Statistical Manual of Mental Disorders (APA, 2014) defines it as a disorder characterized by excessive concern about a series of events or activities. Specific criteria must be determined to consider that a pattern of behaviors should be framed as a Disorder of Mental Disorders—generalized anxiety. Anxiety is a disorder when it affects the patient's daily life because it creates a systematic structure of negative thoughts, excessive worries about the future, feelings of vulnerability, tension, apprehension, nervousness, and even manifestations of intense physical discomfort. These fears of failure, punishment, ridicule, or phobias have a subjective approach, identified as a "*something*," both tangible and social. This something is defined as an anxiety situation, and the intensity depends on the individual and the faithful quality of their perception of reality (Peralta & Cuesta, Trastorno depresivo y depresión en los trastornos del espectro esquizofrénico:¿ son lo mismo?, 2002; Ries, Castañeda Vázquez, Campos Mesa, & Del Castillo, 2012).

According to Peralta & Cuesta (2002), the terms anxiety and depression are terms usually confused because their limits are diffuse; sometimes, they are used as synonyms for anguish or fear (Sierra, Ortega, & Zubeidat, 2003; Martínez-Otero Pérez, 2014; Del Rio Olvera, Cabello Santamaría, Cabello García, & Aragón Vela, 2018).

Both are referred to as an immediate emotional state, symptom, syndrome, disease, or adaptation reaction to an adverse circumstance modifiable over time, where they were submitted to psychological studies; however, current medicine relates them to bodily expressions and causes of anemic symptoms. , where the mental reality of the person has lost contact with their body (Lowen, 2010). It is important to note that anxiety and somatic stress processes are the preludes to depression.

Anxiety can generate severe behavioural and personality problems; however, the important objective of this research is to understand the states of anxiety that individual experiences when facing a specific event or situation relevant to their life, such as education students. Media entering the superior, in which a mismatch is created, raised by the novelty, the constant doubt, and specific cases of anxiety, which cause this sensation of latent alert (Luengo, 2004).

The student associates anxiety with the imposed demands (other people's or their own) concerning their ability to understand and self-control. When academic situations overload him, he performs a self-evaluation of demands; if they overwhelm him, he ends up concluding that he cannot meet them; therefore, he feels that he is facing a situation of humiliation, even danger, justifying his rejection of school (Jadue, 2001).

Anxiety can be considered as a student's normal adaptive response to a threat. At acceptable levels, it can improve performance, even though it should not be the appropriate response, because it exceeds personal coping resources (Vitasari, Abdul Wahab, Othman, Herawan, & Kumar Sinnadurai, 2010; Castillo Pimienta, Chacón de la Cruz, & Díaz-Véliz, 2016). Affronting situations must adopt conscious strategies by the individual that measure their resources (Gantiva Díaz, Luna Viveros, Dávila, & Salgado, 2010). Affronting has two functions, a) regulating stressful emotions and modifying the person's problematic relationship with the anxiety-producing situation (Cabello Fernández et al., 2014).

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Research indicates that groups with low socioeconomic levels have the highest anxiety rate, and the highest incidences are in adolescence and youth than in adulthood (Ortiz, 1997; Miguel-Tobal, Cano-Vindel, Casado-Morales, & Rodríguez-López, 1996). Reyes-Camona, et al. (2017) report that 13 to 15% of the population during their lives suffer from an anxiety disorder that is not diagnosed; This condition can be transitory or become a personality trait prompted by internal or external agents, stimulating physiological or behavioral reactions.

University students may suffer from anxiety to the multifaceted response of the threat of failure in learning assessments, resolution of activities, and problems, and due to the demands of a social and academic nature and their constant stressful environment (Cooper, Downing, & Brownell, 2018). According to Vitasari et al. (id. ibid) student anxiety is exhibited when they show a passive attitude, lack interest in learning, poor performance in assessments, and poor performance in their activities or tasks. The answers reduce efficiency, concentration, attention, and knowledge retention; in students inclined to suffer from it, the lack of assertive execution, lack of organization, insufficient adaptation to learning, and inability to follow instructions are included.

The work of Brown et. al. (2001) offers help to know the alternatives to these symptoms, with the study of the effectiveness of a test that evaluates disorders of this type with the Hamilton test, through 14 items, which describe the symptoms that the anxious patient presents, focusing on the recognition of physical symptoms such as muscle tension, insomnia, respiratory symptoms, among others. The test has 5 Likert values, ranging from the absence (1) to (5), defined as the maximum intensity of the symptom; if the result of the average score is greater than 30, the teste will be considered with anxiety problems. González and Hernández (2017, p. 1), investigated anxiety and performance; for data collection, they used the self-assessment anxiety scale and the personal, socioeconomic, and academic data of the students; In conclusion, they report that the total number of respondents, 15% have severe anxiety and 1% have a maximum degree.

Bertoglia (2005) reaches two conclusions regarding the relationship between anxiety and learning: a) the effect that anxiety has on learning depends on the type of task to be learned if the activity is of intellectual elaboration so that its learning requires understanding and creativity, anxiety plays a lesser role, explaining why some Educational Experiences can be more stressful than others, according to their skills and, b) the effect of interference in the conclusion a), is more intense in students who have a school competitiveness median. Interestingly, the student with average intelligence suffers more than the one with superior intellect because the first ones has greater emotional assertiveness to control anxiety. The average perceives the possibility of failure closer, requiring more positive reinforcement in classroom.

Depression

Depression is a condition accompanied by worry, decay, insecurity, sadness, and negative thoughts towards oneself (APA, 2014), accompanied by insomnia, lack of appetite, weight loss in extended periods, isolation, consumption of drugs, and markedly low self-esteem. Serrano et al. (2013) psychologically explain that when depression is present in the process of the mental stages that allow the individual to become aware of himself and the environment, they generate a distorted result caused by the existence of cognitive errors that lead the individual to perceive reality negatively. These errors are the selection, magnification, and generalization of negative information, such as errors and personal failures, leaving aside and minimizing the successes. Stress is considered the prelude to the anxious response, the fear of a state of tension due to a specific threatening event; however, anxiety leaves the exterior aside and settles as an essentially personal problema (Barquín, García, & Ruggero, 2013).

The World Health Organization reports that suicide is the fourth leading cause of death globally between the ages of 15 and 29 (OMS, 2021). n Mexico, almost six million adolescents between 12 and 22 face this symptomatology (DGDG, 2019), with possible suicidal solutions

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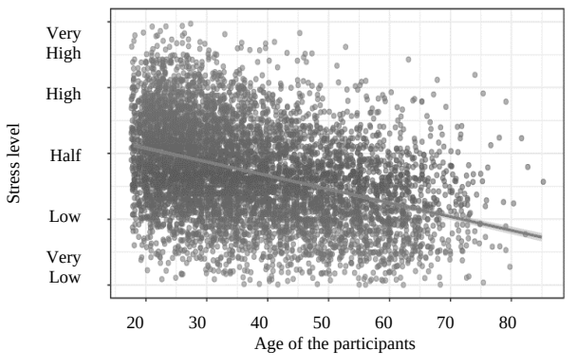
COVID-19 and emotional disorders

Considering all these factors, the information received in student admission surveys must be analysed in detail due to the impact of the COVID-19 pandemic during the lockdown period that began at the end of 2019, causing risk situations in the population, such as the mandatory quarantine of approximately two years, fear, frustration, and perception of economic, health, and social thread (Bao, Sun, Meng, & Lu, 2020; Garfin, Silver, & Holman, 2020).

According to the International COVIDiSTRESS project, where a digital survey distributed in 50 countries was applied (with a total of 158,771 respondents and of these 6,427, corresponding to Mexico), it was reported that stress has higher levels among young people aged 20 to 30 years, being inversely proportional to age (Pérez-Gay Juárez et al., 2020 p. 2) (Graphic 1).



Graphic 1 Level of stress about the age of the respondent's
Source: (Pérez-Gay Juárez et al., 2020 p. 5)

The UNESCO International Institute for Higher Education in Latin America and the Caribbean (Alvarez, 2020, p. 16) reported that 75% of surveyed university students participating in levelling and support programs are the most vulnerable to experiencing anxiety and depression. In another investigation carried out in China, with a total of 89,588 university students, 41% presented anxiety symptoms, including second, third, and last-year students, poor economic situation, and low social support (Fu et al., 2020, p.16); ensuring that capacity in psychological skills must be strengthened to mitigate the problems caused by COVID-19.

Other studies focused on the impact of the pandemic show that after the crisis, the consequences in higher education will be reflected in academic performance and in the development of trajectories linked to university actions, according to the results of the survey applied to 297 students from the University of Social Sciences in Bogotá, Colombia (Navas, Chiriví, & Camargo, 2023). Even within a survey applied to nursing workers (60 people), the results show that 76.67% of those surveyed affirm an emotional impact on anxiety, fear, stress, anger, and depression (Cervantes Lupaca, 2021).

Methodology

Diagnostic-type tools for incoming students

Widespread use of these surveys in Mexican universities to find out information about their applicants for admission and to make decisions according to the profiles of the different students, both in the social, economic, and psychological strata.

The surveys can be conducted on various topics; for example, the Autonomous University of Chihuahua detected that the success of the students is a function of their positive self-perception (Ornelas, Blanco, Gastélum, & Chávez, 2012); in this study, the self-efficacy factors were resolved with questions about their communication, care, and excellence.

Another case is applied to new students from the Azcapotzalco and Cuajimalpa units of the Autonomous University of Mexico, where several characteristics require analysis, such as commuting, school history, academic practices in high school, cultural consumption, use of the internet, cultural resources, and materials available to them for their university studies. Among the interesting points of cultural consumption are attendance at sporting events, concerts of different musical genres, provision of books, and attendance at conferences, museums, art exhibitions, dance, opera, theatre, cinema, or festivals in towns or neighbourhoods.

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From the use of the Internet, they generate questions about the use of email, chatting, searching for information, downloading music, buying online, receiving information, downloading software, watching videos, finding a partner, looking for a job, playing games, pornographic pages, watching movies or programs, listening to music, reading books, magazines or newspapers, discussion forums, file sharing, phone calls, social networks or blogging (De Garay, Miller, & Montoya, 2016).

The research offers an example of the importance of knowing these data by Prado et al. (2019) that relates the personality factor to learning styles, concluding that the predominant learning style is auditory in the administrative area for first grades and that these students are discreet, with a temperamental inclination, cautious in their emotional expressions, uncompromising and critical in their appearance.

In this exact order, Becerra and Plata (2021) present other characteristics that are considered to be evaluated in students prior to entering the university: the physical state through medical review, observation, and registration, student interests, motivation with which account at the entrance of the university, aptitudes to know their aspirations, the academic history and study habits. Within the Tutorial Action Plan, the Autonomous University of the State of Morelos (Plan de Acción Tutorial. (18-20), 2018) , the points considered for selecting its future students include their demographic, academic, socioeconomic profile, and vocational orientation.

The Student Income Profile Consultation System at the University of Guanajuato (SCOPI UGTO); allows obtaining information in a systematic and timely manner on young people who applied for admission through the registration of ID cards as well as on admitted students, based on the design of strategies to prevent falling behind and dropping out of school, as well as making decisions that facilitate a successful transition during their student career (UDG, 2022).

Internationally, the Institutional Repository of the Technological University of Panama is another institution that has a source of free access to data to know the profiles of applicants (UTP-Ridda2, 2022).

Information tool of the Universidad Veracruzana

The first descriptive and exploratory survey implemented by the Income Profile Consultation System (SCOPI) by the Universidad Veracruzana (UV) to applicants for upper secondary education who wish to enter their academic ranks, was in the year 1997, collecting information for 25 years to provide it to the General Directorate of School Administration. SCOPI had undergone modifications in its configuration since 2014, when it was put into practice. Currently, it is applied in the four regions, reporting aptitudes, personal characteristics, school of origin, minimum and maximum scores, and presentation of graphs of the information collected (UV-DGCU, 2022; UV-DGAE, 2022).

Furthermore, said mechanism is also available to area directors, faculties, and their academic secretaries, thus knowing the resources of the students for their studies, abilities, knowledge, expectations, and high school graduation profile. As in most of these types of surveys, the Likert style is used to evaluate the qualitative opinion; said survey is divided into four categories: personal, academic, background, and graduation profile (Figure 1).

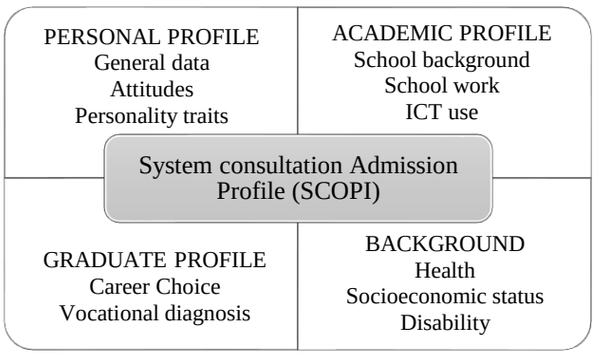

Figure 1 Integrating diagram of the profiles in SCOPI of the Universidad Veracruzana.
Source: Own elaboration

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The Personal Profile, provides knowledge about a) communication skills and attitudes, b) attitudes, c) life project and approach to goals to be achieved, d) personality traits covering characteristic aspects of a biological, psychological, and philosophical nature that define an individual, e) health that integrates features of the different dimensions that make up the individual in an integral way (biological, neurological, physical, psychological, mental, among others), f) socioeconomic conditions, which allow satisfying fundamental needs for the sustenance of human life and g) self-management to know the capacity that the student must have to attend and follow up on their own, to their school affairs. In this category, the academic profile aims to understand the choice of career and obtain a vocational diagnosis.

School work or graduation profile allows one to know a student's study habits, which can set the tone to develop a successful school trajectory. The compliance and participation variable are integrated because the student's school irregularity may result from practicing a habit or pattern of indiscipline. If so, corrective measures can be applied from the tutorial. The recommended characteristic aspects are punctual attendance, paying attention, participating in class, carrying out class activities on time, following instructions in carrying out exercises in the classroom, planning school tasks, and organizing study time, and punctual delivery of tasks.

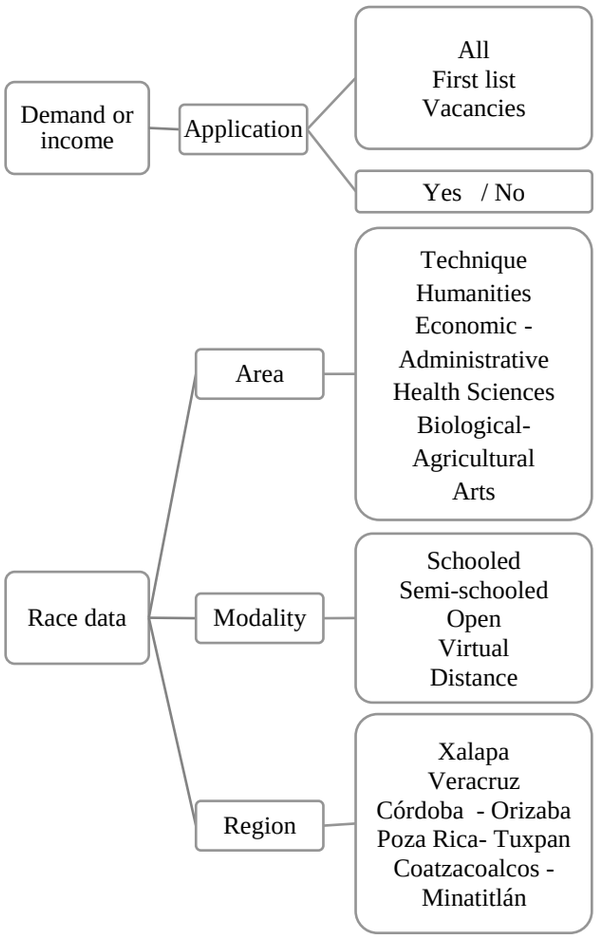

Figure 2 Independent variables correlated according to the dependent variables: Anxiety - Stress and Depression
Source: Own elaboration

The part of the history allows us to know aspects related to health; in them are the variables of Stress - Anxiety (StAn) and Depression. The SCOPI information system allows for collecting information from 2015 to date, with which the trend of these two variables of future university students was analyzed.

The information can be classified and subdivided among total applications, final registration, selection of the region of affiliation, area of knowledge, and course modality (Figure 2).

Results

The UV has received, since 2015, from 40,000 to 45,000 applications for admission from the state of Veracruz, Mexico, having the capacity to accommodate from 33 to 42%, that is, from 14,000 to 17,000 students, depending on its educational offer.

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Table 1, contains the data of the affirmative answers to the variables StAn (Stress and Anxiety) and Depression, considering both the applicants and those finally enrolled. Both variables show an increasing trend; if the years 2015 and 2022 are compared, we observe that the variable StAn with a value of 647% in applicants and 591% enrolled, and Depression of 360% in applicants and 342% enrolled.

Year	Applicants (Students)	Inscribed (Students)	Applicants (%)	Inscribed (%)
Variable Stress-Anxiety (StAn)				
2015	1,585	627	3.8	4.2
2016	3,349	1,324	8.0	8.5
2017	3,279	1,289	7.6	8.3
2018	4,874	1,807	11.0	11.2
2019	5,599	2,136	12.7	13.5
2020	6,782	2,947	17.0	18.1
2021	9,319	3,519	20.7	21.0
2022	10,757	4,115	24.8	25.0
Variable Depression				
2016	949	386	2.1	2.2
2017	904	379	2.3	2.5
2018	1,296	532	2.1	2.4
2019	1,624	653	2.9	3.3
2020	2,121	958	3.7	4.1
2021	2,681	1,050	5.3	5.9
2022	3,209	1,254	6.0	6.3

Table 1. Values of the affirmative answers to StAn and Depression of the applicants to enter the UV.
Source: Own elaboration with data from SCOPI, Universidad Veracruzana

The most significant turning point was in 2020 (70% increase), concerning 2019, when the confinement due to the COVID-19 health pandemic began, without showing a decrease to date.

Area of Knowledge in the variables StAn and Depression

Graphic 2a is expressed the number of enrolled students who answered positively to the StAn variable, and Graphic 2b reports the results of the Depression variable. In both Graphics (2a and 2b), the proportionality is added based on the total of each subgroup (Eq. 1)

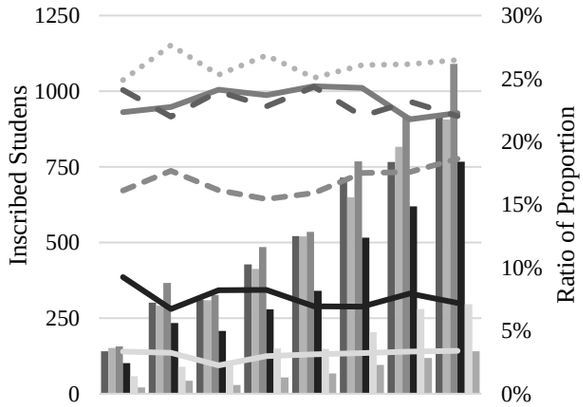
$$\text{Ratio (\%)} = \frac{\text{Students with a positive response}}{\text{Total students in each subgroup}} \qquad (1)$$

Similarly, Graphics 3 and 4 use the same graphic methodology to understand the results and draw conclusions, counting only the students finally enrolled.

This methodology offers recommendations that can be implemented in the process of academic accompaniment carried out by the university tutorial coordination.

Each graphic offers a different subdivision per inscribed student, being Graphic 2 corresponds to the division of knowledge area (Technical Area, Humanities, Economic - Administrative, Health Sciences, Biological - Agricultural and Arts), Graphic 3 by the modality of studies; the subdivisions: Schooled, Semi-schooled, Open, Virtual and Distance; and finally, Graphic 4 by region to which they decided to join, with subdivisions: Xalapa, Veracruz, Córdoba - Orizaba, Poza Rica - Tuxpan and Coatzacoalcos - Minatitlán.

According to Graphics 2a and 2b, it is the students enrolled in the Economic-Administrative area who report a significant increase in StAn and Depression symptoms, followed by Technical, at the midpoint this Health Sciences and below Arts although the appreciation of young people gives us as a result that the Depression is 50% less than StAn.



Graphic 2a

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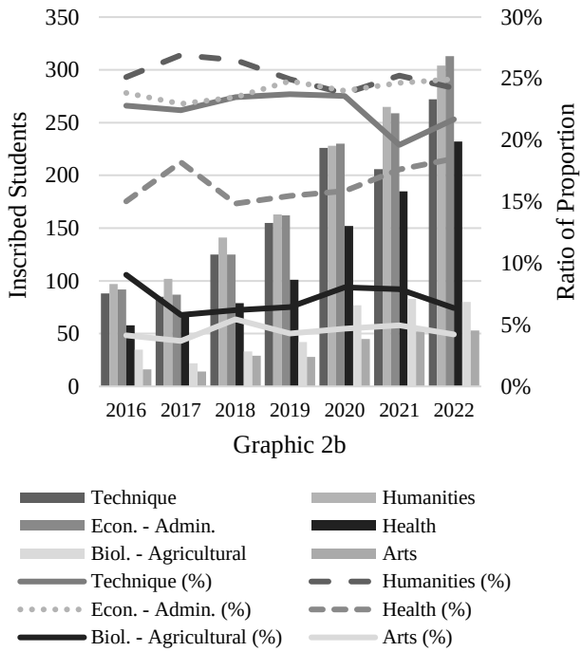


Graphic 2b

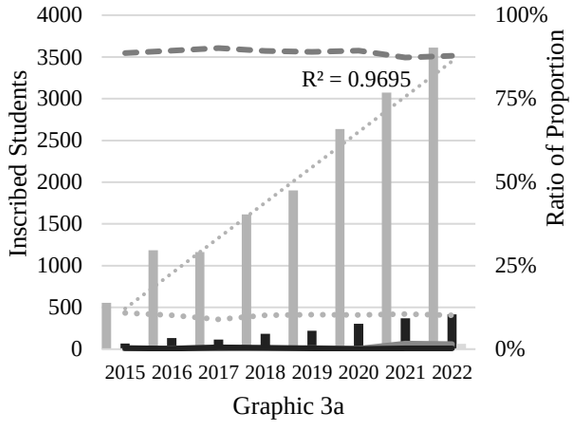
Graphic 2 a) Total values of students inscribed with StAn "Yes" and their Proportional Relationship and, b) Total values of students inscribed with Depression "Yes" and their Proportional Relationship, both depending on the Area of Knowledge
Source: Own elaboration

Regarding the proportion, it is observed that almost 25% of the inscribed students in Economic-Admin., Technical and Humanities suffer from StAn and Depression, followed by 17% in Health Sciences, Biological - Agricultural with 8% and finally, Arts with 3%.

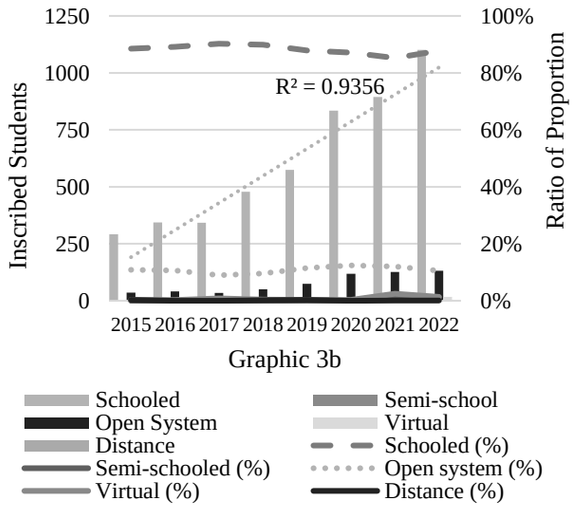
Study modality in the StAn and Depression variables

In all cases, the school system presents the highest StAn and Depression, with Depression being almost 75% less than StAn; however, the trend is high in both cases because StAn presents an R^2=0.9695 and Depression an R^2= 0.9356.

In both cases, the Open system corresponds to 10%, and the other cases (semi-school, virtual, and distance) have less than 2%. Although there are few values for the Semi-schooled category (2021 and 2022), since it was implemented with limited enrollment capacity and in response to COVID-19, it is interesting that it has a stable trend (R^2= 0.528), even under the open system.



Graphic 3a



Graphic 3b

Graphic 3 a) Total values of students inscribed with StAn "Yes" and their proportional relationship,nb) Total values of students inscribed with Depression "Yes" and Proportional relationship, both depending on the Study Modality
Source: Own elaboration

Region of Ascription in the StAn and Depression variables

Of all the regions of affiliation, Xalapa, the capital of the State of Veracruz, is the one with the most significant educational capacity, both in terms of infrastructure and because it is where the rectory of the Universidad Veracruzana is located. In this region, the students refer to greater StAn and Depression.

In Graphic 4a, StAn has an R^2=0.9696; depression has a strong impulse from 2019 to 2020. In proportion, almost 50% of the students refer to StAn and Depression, followed by Veracruz with 20% of its enrolled enrollment, Córdoba -Orizaba and Poza Rica-Tuxpan from 11 to 13%, and Coatzacoalcos-Minatitlán with 1%.

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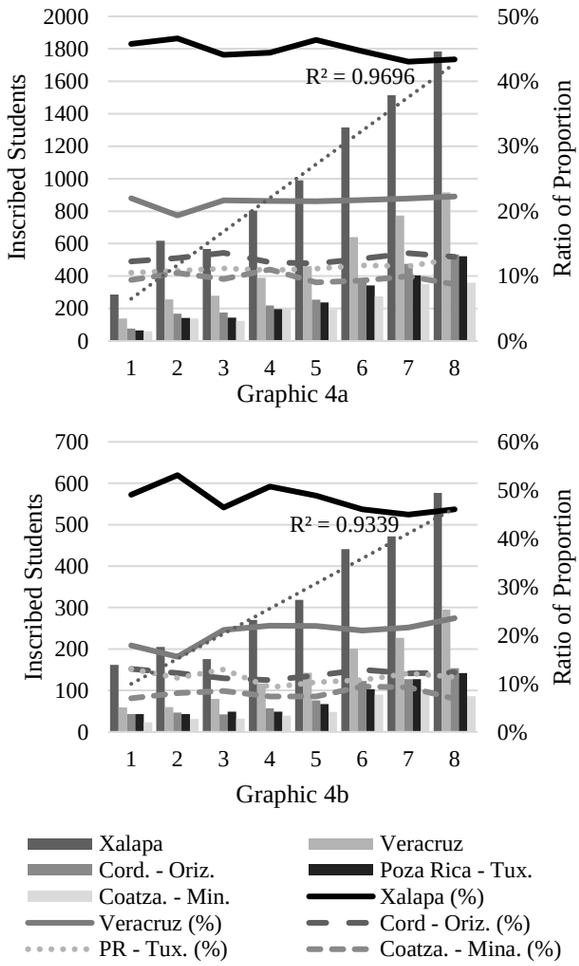
It is necessary to recognize how the enrollment of foreign students (vulnerable group) influences the exposed values, where Xalapa contains a more significant number of students in this condition, where young people must solve their basic needs for housing, food, mobility, and services, as well as managing your financial and time resources.



Graphic 4. a) Total values of students enrolled with StAn "Yes" and their proportional relationship, b) Total values of students inscribed with Depression "Yes" and the proportional relationship, both depending on the Affiliation Region.
Source: Own elaboration

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Conclusions

The results show that the trends of these pathologies are on the rise; accordingly, the students are not in adequate conditions for the teaching-learning process, resulting in poor school performance, and dropping out of university studies as well as an anemic emotional state.

The literature indicates some physiological, emotional, and behavioral symptoms to observe in students, which allow us to detect, as in the case of depression, suicidal solutions. Therefore, the accompaniments or first tutoring contacts become the appropriate institutional resource to put this situation on alert and redirect it to specialists.

Of the Tutorial Action Plans, the Autonomous University of the State of Morelos (Plan de Acción Tutorial (18-24), 2021), applies a series of aspects that were already valued when the students had been staying at the university for a while; however, those that are mentioned can be rescued for diagnose prior to the stay: integration with colleagues, the definition of personal goals, construction of a life project, recognition of strengths and weaknesses as a student, assuming responsibilities towards academic commitments, independent and well-founded decision-making, straightforward communication of ideas and feelings and constructive, development of ethical attitude for professional training, time management, planning of school and extracurricular activities, acquisition of study habits, acquisition of skills for self-learning, independent work, and teamwork, development of skills to improve the performance and knowledge of different data sources and search for information.

Each category provides information necessary for decision-making prior to the development of the student's academic life.

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Based on what was discussed in previous paragraphs and due to some very similar symptoms, there is a fragile line that "*divides*" the different emotional disorders such as stress, anxiety, or depression, which puts performance or academic performance at risk, also your health. Comprehensive, highlighting the need for timely detection of these conditions to take timely measures.

It is interesting to note that the student with average intelligence suffers more than the one with superior intellect because the latter have greater emotional assertiveness to control anxiety, and the average perceives the possibility of failure closer, therefore requiring more positive reinforcement in the classroom; therefore the need to pay attention to the two risk groups identified, foreigners and average to lower academic performance, as well as students from Administrative areas who report higher levels of stress, are highlighted.

A proposed solution is support groups generated within the safe spaces of the universities, which create an emotional support network to share similar experiences, generating the first contact opportunity to detect problems that can be treated psychologically (UV, 2023). The moderator of the support groups must have the relevant training to detect cases, and in this investigation, it is remembered that the treatments can be both psychotherapeutic and pharmacological.

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Predicting academic performance grades of control student using a LSTM neural network

Predicción de las notas de rendimiento académico de un alumno de control mediante una red neuronal LSTM

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Abstract

The evolution of artificial intelligent (AI) allows the development of new neural networks models associated with academic process such as: research, teaching-learning, and evaluation. Typically, in evaluation, the teacher verifies the correct use of the competency by the students. Deep Neural Networks has a significant impact to automate grading process for certain types of subjects. In skills learning process, especially in control and automation, the student must develop professional tasks. In this paper, a LSTM recurrent neural model is presented as an evaluation tool to classify the level of the skill in sufficient, prominent, or automated, using a temporal series associated with task performance. The model contains 5 layers, with SoftMax activation function and Adam optimizer. A non-recurrent Neural Network (NN) with 5 layers, RELU activation function and Adam optimizer, is developed to compare results. The results show an improvement in the LSTM model with 91.7% accuracy, 92.4% precision and 60% less requirement in the training and validation process. The results allow the proposed LSTM model to be a tool-assistant for the evaluation of control and automation skills.

LSTM, SoftMax, Adam, Recurrent, Activation, Neural, Competency, Accuracy

Resumen

La evolución constante en Inteligencia Artificial (IA) permite el desarrollo de nuevos modelos de redes neuronales en procesos académicos de investigación, enseñanza-aprendizaje, y evaluación. Típicamente, en la evaluación, el docente verifica el correcto uso de la competencia por los estudiantes. Las redes neuronales profundas presentan un impacto significativo para automatizar el proceso de calificación para ciertos tipos de materias. En el proceso de aprendizaje de competencias, especialmente en control y automatización, el alumno debe desarrollar tareas profesionales. El presente trabajo, propone utilizar un modelo de red neuronal recurrente LSTM para la evaluación de estudiantes, mediante una secuencia de tiempo asociada a la realización de tareas, con el fin de clasificar la competencia en suficiente, destacado y autónomo. El modelo contiene 5 capas, función de activación SoftMax y optimizador Adam. Se desarrolló una Red Neuronal (NN) no recurrente de 5 capas, función de activación RELU y optimizador Adam, para comparar resultados. Los resultados muestran una mejora en el modelo LSTM con 91,7% de precisión, un 92,4% de precisión, y 60% menos de exigencia en el proceso de entrenamiento y validación. Los resultados permiten que el modelo LSTM propuesto sea una herramienta-asistente para la evaluación de habilidades de control y automatización.

LSTM, recurrente, competencia, Recurrente, Activación, Neuronal, Competencia, Exactitud

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Introduction

Nowadays, cognitive technologies **(Kuzior, 2022)** and artificial intelligence have revolutionized several fields, including education. Student assessment is a necessary aspect of the education system, providing information such as performance, understanding, and progress. Traditional assessment based on written exams and subjective grading has limitations in objectivity, consistency, and the ability to capture the veracity level of a student's knowledge. Typically, student evaluations are slow, subjective, and biased. Developments in artificial intelligence (AI) and machine learning have a high impact on evolving the assessment processes for students, which has garnered significant interest in recent decades **(Xieling, 2022)**.

Technology in classrooms has helped deliver instruction based on student learning behavior **(Cheng, 2021)**. AI measures and understands learning processes, such as student training and performance evaluation, in a more precise, efficient, and personalized manner **(Arun, 2022)**. With artificial intelligence technologies, it is possible to design adaptive assessment systems that align with the student's level and pace of learning. It is feasible to analyze individual student data, providing objective assessments. An algorithm can study responses, tasks, and evaluations without biases or human subjectivity **(Sadiku, 2022)**, **(Bravo, 2023)** thereby enhancing accuracy and efficiency, reducing the time and effort required by teachers, and ensuring impartiality in student performance evaluation **(Ahmad, 2022)**. AI provides continuous monitoring to generate favorable personalized feedback based on students' strengths, weaknesses, and learning styles.

AI algorithms can process large datasets to identify patterns, trends, progress, and learning gaps in adapting teaching strategies. There is a high impact on finding statistical methods for diagnostic classification students **(Cui, 2016)**, Studying and applying artificial neural networks (RNN).

Deep Learning implementation in student assessment processes presents significant challenges such as data availability, interpretation of results, adaptability, and personalization of assessment.

K-Nearest Neighbors, Naïve Bayes, and Support Vector Machine are machine learning techniques for classifying results **(Yahya, 2013)**. The validation data analysis, using learning algorithms like Deep Learning, confirms that the evaluation results related to student performance (Hou, 2021) will be reliable when grading students because it can discover hidden relationships and patterns in the data.

The article presents an evaluation method that involves a time-based test sequence to obtain a dataset of 600 samples. Moreover, the model uses a 5-layer LSTM algorithm. The model is compared with an RNN, a non-recurrent neural network model, resulting in 91.7% accuracy and 92.4% precision.

Section 2 contains the background, followed by the state of the art in Section 3, the design of the classification model in Section 4, tests, and results in Section 5, and finally, the conclusions in Section 6, along with references in Section 7.

Research Works

Neural Networks (NN)

Methods like traditional artificial neural networks (ANN) have been developed to resemble the connectivity patterns of human brain neurons to perform tasks with improved performance through learning, training, and continuous improvement **(Kardan, 2013)**. ANNs can predict and compare a given system **(Martinez, 2023)**. A neuron allows different inputs to apply to an output. NNs can characterize the connections between neurons (topology) and the method for obtaining the optimal connection weights (training and learning algorithm) and activation function **(Rodríguez, 2021)**. The mathematical model function of the NN is presented in Equation 1.

$$\widetilde{\boldsymbol{Y}} = f\left(\widetilde{\boldsymbol{X}}, \widetilde{\boldsymbol{W}}\right) \quad (1)$$

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Where $\tilde{Y}$ y $\tilde{X}$ are the input and output vectors. $\widetilde{W}$are the weight parameters that represent las internal connections between NN.

ANNs are organized into layers: an input layer, which collects data into a set of features, one or more hidden layers, which process the input values, and an open-loop output layer. These networks are used for classification problems and pattern recognition in non-sequential data. The neurons value *j* and vectors $\tilde{Y}$are computed by the weighted sum of input elements from x and w. Where w is updated recursively (equation 2).

$$y_j = \theta\left(\sum_{i=1}^{N_i} w_{ij} x_i\right) \quad (2)$$

θ is the activation function (transfer function), N_i is the total number of connections of the *j* neuron and x_i is the output value of the past layer i neuron. The hyperbolic tangent function is used as the activation function (θ) to transfer the value of the weighted sum of inputs to the output layer.

Recurrent Neural Network (RNN)

Recurrent Neural Networks (RNNs) are a type of artificial neural network designed to process sequential data. Recurrent connections create a form of internal memory or state that allows capturing dependencies and patterns in sequence with the length of the input variable (**Karim, 2019)**, **(Lau, 2021)**.

Pascanu et al. **(Pascanu, 2013)** propose an RNN to maintain a hidden vector **h** as a state that is updated at time ***t***, with a step activation function (equation 3 and 4).

$$\boldsymbol{h_t} = tanh(\boldsymbol{W h_{t-1}} + \boldsymbol{I x_t}) \quad (3)$$

$$\boldsymbol{y}_t = softmax(\boldsymbol{W h}_{t-1}) \quad (4)$$

Where *tanh* is a hyperbolic tangent function, x_t is the input vector at time ***t***. is the recurrent weight matrix, and **I** is the projection matrix. In the prediction y_t, **h** is a hidden state, **W**, is the weight matrix, and SoftMax normalizes the model's output. The sigmoid function is denoted as **σ** in equation 3. Deep RNNs can be formed by stacking the output of one RNN as the input to another (equation 5).

$$\boldsymbol{h_t^l} = \sigma(\boldsymbol{W h_{t-1}^l} + \boldsymbol{I h_t^{l-1}}) \quad (5)$$

The basic architecture of an RNN can be used to address various problems. One issue that can arise with an RNN is that they can be affected by vanishing gradients, which impacts the training of the sequential network (network weights become very small - vanish and very large - explode, making the network unstable). LSTM (Long Short-Term Memory) or a GRU (Gated Recurrent Unit) could solve the problem.

Long Short-Term Memory (LSTM)

LSTMs are used when computational resources are limited. They are recurrent architectures. Unlike a traditional RNN, LSTM cells have a memory unit called the memory cell or long-term memory. The memory allows the network to retain relevant information throughout the sequence. Equations 6 to 11 show the basic structure of an LSTM cell **(Song, 2020)**.

$$i_t = \sigma(W_{ri} R_t + U_{hi} h_{t-1} + b_i) \quad (6)$$

$$f_t = \sigma(W_{rf} R_t + U_{hf} h_{t-1} + b_f) \quad (7)$$

$$\tilde{c}_t = tanh(W_{ri} R_t + U_{hc} h_{t-1} + b_c) \quad (8)$$

$$c_t = f_t \odot c_{t-1} + i_t \odot \tilde{c}_t \quad (9)$$

$$o_t = \sigma(W_{ro} R_t + U_{ho} h_{t-1} + b_o \quad (10)$$

$$h_t = o_t \tanh(c_t) \quad (11)$$

Where $\boldsymbol{\sigma}$ is the sigmoid activation function, $\boldsymbol{R_t}$ is the input feature matrix over time ***t,*** $\boldsymbol{W_{ri}, W_{rf}, W_{rc}}$ ***y*** $\boldsymbol{W_{ro}}$, denote the matrix of weights between the input layer and the input gate, the forget gate, the memory cell and the output gate , respectively. $\boldsymbol{U_{hi}, U_{hf}, U_{hc}}$ ***y*** $\boldsymbol{U_{ho}}$, denote the matrix of weights from the hidden layer to the input gate, the oblivion gate, the memory cell and the output gate, respectively. $\boldsymbol{b_i, b_f, b_c}$ ***y*** $\boldsymbol{b_o}$, denote the offset value of the input gate, forget gate, memory cell, and output gate, respectively.

Loss function

The loss function is used to quantify the discrepancy between the outputs predicted by the network and the actual values of the training data. The loss function is defined in equation 12 **(Akbari, 2021), (Chen, 2022)**.

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$$L(\hat{y} - y) = -ylog(\hat{y}) - (1 - y(\log(1 - \hat{y})) \quad (12)$$

Where $\boldsymbol{y}$, denotes the actual classification of the sample and $\hat{\boldsymbol{y}}$, represents the result of pattern recognition.

SoftMax

SoftMax is an activation function used in the output layers of a neural network for multiclass classification problems. Equation 13 and 14 shows the SoftMax description.

$$p\left(\frac{z}{a}\right) = softmax(w^{(s)}h_k + b^{(s)} \quad (13)$$

$$z = argmax\left(p\left(\frac{z}{x}\right)\right) \quad (14)$$

Where **z** is the probability that the prediction is correct, **x** is the input, **h** is the hidden state.

Adam optimizer

Adam is a first-order optimization algorithm for stochastic functions based on adaptive estimates of lower-order moments used in the training of deep neural networks **(Kingma, 2020)**. Adam maintains a set of moving averages of gradients, which are calculated during the training process and used to auto-adjust the learning rates of parameters. The algorithm combines the advantages of the SGD with the momentum gradient algorithm and RMSprop, which uses a window to consider the most recent gradients **(Son, 2020)**. Compute for the moment gradient at time **t** (15), updating the biased estimate of the first moment (16), updating the biased estimate of the second raw moment (17), calculation of the first moment estimates with bias correction (18), Compute of the second moment to estimate the bias correction (19), parameter update (20):

$$g_t = \nabla_\theta(\theta_{t-1}) \quad (15)$$

$$m_t = \beta_1 m_{t-1} + (1 - \beta_1)g_t \quad (16)$$

$$v_t = \beta_2 v_{t-1} + (1 - \beta_2)g_t^2 \quad (17)$$

$$\widehat{m_t} = \frac{m_t}{1-\beta_2^t} \quad (18)$$

$$\widehat{v_t} = \frac{v_t}{1-\beta_2^t} \quad (19)$$

$$\theta_t = \frac{\theta_{t-1} - \alpha * \widehat{mt}}{\sqrt{\widehat{v_t + \varepsilon}}} \quad (20)$$

Related work

Luo et al. **(Luo, 2022)** analyze a method for piano teaching implementation using a neural network (NN) model, which evaluates piano performance and simulates teachers to guide students in their exercises.

With the impact of the COVID-19 pandemic, teaching methods evolved to be remote, offering online classes to mitigate learning issues. To ensure that students participate effectively, Bhardwaj et al. **(Bhardwaj, 2021)** introduce an innovative algorithm based on Deep Learning, using Convolutional Neural Networks (CNN) to monitor students' emotions in real-time, including feelings like anger, disgust, fear, happiness, sadness, and surprise. In addition, the work includes algorithms like MES (Mean Engagement Score) for facial landmark detection to gauge feelings. Both methods enhance and innovate digital learning.

Nuha Alruwais et al. **(Alruwais, 2023)** conducted a study using RNNs to predict student interactions in the virtual classroom (e-learning), allowing the prediction of a student's engagement. A classification of machine learning (ML) algorithms is used for machine learning and student evaluation through cross-validation and different metrics to optimize ML models. Parameters such as accuracy, precision, recall, and AUC scores (Area Under the Curve) are evaluated, as well as the ROC curve (Receiver Operating Characteristic curve), used to display the classification model's performance, showing the true positive and false positive rates. The model predicts that a student has a high level of engagement, achieving an accuracy of 94.64%.

Evaluating students' cognitive abilities in academic contexts can provide information to identify and assess their cognitive profile and create personalized teaching approaches. Orsoni et al. **(Orsoni, 2023)** compare two clustering techniques for students based on their cognitive abilities. The first compared method was SOM (Kohonen's Self-Organizing Map), and the k-means method, while the second method was AdaBoost and ANN (Artificial Neural Network).

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The work demonstrates that the first method is better to solve the problem, but the ANN method provides better classification. They suggest hybrid techniques to improve the reliability of clustering and the effectiveness of the results.

Alsabhan et al. **(Alsabhan, 2023)** propose a method to identify potential cheating incidents in exams using machine learning approaches. LSTM (Long Short-Term Memory) for modeling sequential data, which retains information from the previous input, and the Adam optimizer to find an optimal set of parameters that minimize the loss function, enabling the neural network to make accurate predictions. The implemented model achieves an accuracy of 90% in training and 92% in system validation. The implemented method creates academic performance prediction models and identifies vulnerable students with problematic behaviors.

Author	DataSet/Application	Results	Precision
Al-Azazi, et al. (2023)	A model ANN-LSTM is proposed to predict student performance using artificial neurons, with a dataset of 32,593.	The results show that the ANN-LSTM model achieved the best results among the RNN and GRU models.	70% accuracy, a value above 53%, and 57% for the other models.
Jha, et al. (2022)	The work proposed SVM, LSTM, and BILSTM models to address traffic and tracking of complaints on the student portal through the implementation of Foul/Hate Detection using Machine Learning and Deep Learning technologies, with a dataset of 11,325.	The results show that the LSTM model outperformed the other SVM and BILSTM models.	84% Precision
Tao, et al. (2022)	The work proposed a deep memory network PI-DMN based on ABSA aspects to assess the mental health of students through LSTM using a dataset of 52,106.	The results show that the LSTM outperformed with values above other models.	Precision between 80 and 85%
Rahman, et al. (2021)	The work proposes a language model to evaluate and repair source code using a BiLSTM with a dataset of 2,482.	The BiLSTM model outperforms the unidirectional LSTM and RNN models.	97% precision
Minn, et al. (2020)	The work proposes a BKT-LSTM model that predicts student performance in temporal ability assessment through BKT evaluation, using a dataset of 58.	The performance of BKT-LSTM is significantly better than that of the more advanced models in the tested datasets such as DKT and DKVMM.	85% accuracy, with a 10% improvement compared to the other models.

Table 1 Related work

Evaluating whether students' skills and competencies meet current industry requirements is a topic that has evolved in companies that express an interest in hiring employees certified in the domain of activities related to their profession.

The literature review presents some areas of opportunity to develop competency assessment systems, such as using recurrent neural network models for grading students' performance in specific topic-related tasks. The rapid development of new sequential processes can demonstrate certification of competencies over time. The present work exploits these opportunity areas in the design of a new LSTM model for student evaluation.

Classification model design

The evaluation model for students provides an interactive, intelligent, and automatic design to assist professors in control competences evaluation. The method architecture presents three main blocks: **1) Test sequence development. 2) Creation of the time-series dataset. 3) Development of the LSTM deep learning model for classifying students as sufficient, outstanding, or autonomous.** The Figure 1 shows the overall architecture.

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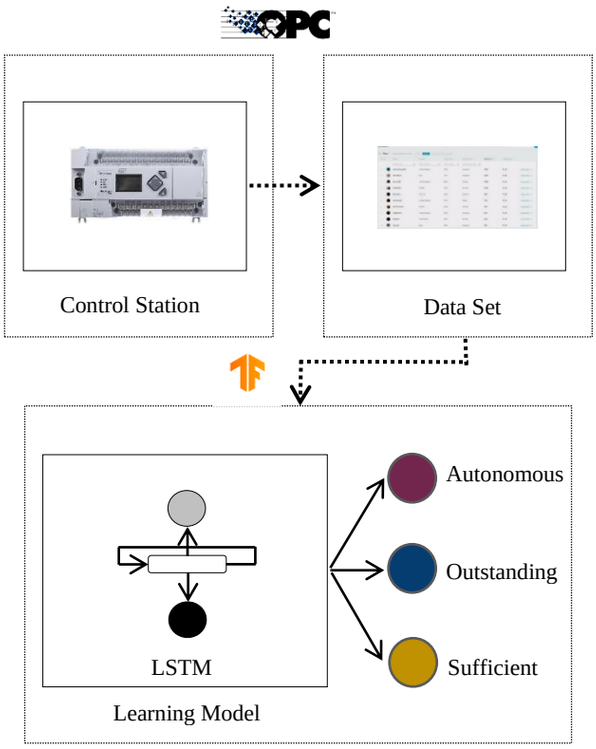

Figure 1 Overall system architecture

The test sequence (1) is a series of 5 main tasks in the control field and automation, which allows for obtaining a time sequence of the student's performance. In other words, the student develops progressive activities to accumulate time until completing the entire series. The tasks are related to PLC configuration, PLC programming, and troubleshooting in the automatic control system. The Table 2. shows the test configuration for data acquisition.

No.	Task	Evaluation	Equipment	Time Min
0	Sensor and actuators configuration	Equipment Installation and functional tests	Pneumatic valves and actuators, PNP and NPN sensors	5
1	Analog Sensor Configuration	Equipment Installation and functional tests	Voltage and Current Sensors	5
2	Troubleshooting	Quantity of fixed errors	PLC y CPU	10
3	PLC Programming	Sequential Programming process	PLC y CPU	20
4	Instrumentation Variables	Digital and Analog Monitor tags	PLC y CPU	20

Table 2 Tasks description

The completed tasks are monitored by time within the PLC program, which records a timestamp each time the student reaches the goals in the activities. In the first activity, the student has to configure two NPN inductive sensors and 2 PNP inductive sensors, and two bistable solenoid valves 5/3 with two pneumatic piston-type actuators. The student finishes the activity when the inputs and outputs signal proper function in the PLC program. The Figure 2 shows the completed configuration diagram of Task 1.

Figure 2 Student task 1

In the second activity, the student must connect an analog position signal and configure the signal acquisition filter. The task concludes when the student correctly scales the signal. The third activity is based on the student finding a wiring fault in the proposed configuration, presented by the evaluator. The task concludes when the student correctly identifies the fault or when the maximum time elapses. In the fourth activity, the student must program a pneumatic sequence equation using one of the step-by-step programming methods or a sequencer. The task concludes when the automatic mode of the sequence is successfully achieved. The Figure presents an example of the pneumatic sequence task.

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In the final activity, the student performs an instrumentation of the analog position variable by implementing a Kalman filter and defined thresholds. The task concludes when the student programs the position levels: near, intermediate, and far. Figure 3 shows a student using a panel view Allen Bradley to develop the level instrumentation.

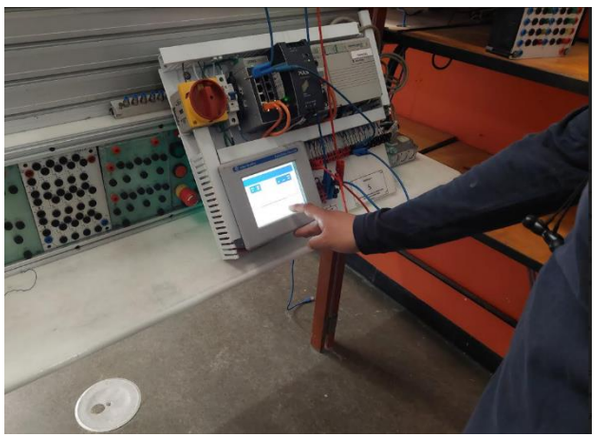


Figure 3 Student task 4

Typically, in deep learning LSTM, the creation of datasets for classification is of dynamic nature **(Ameur et al, 2020)**. The test sequence captures a time series of performance, describing the competency acquired by the student to solve control tasks. The Figure 4 shows three performance series of students categorized as sufficient, outstanding, and autonomous over time.

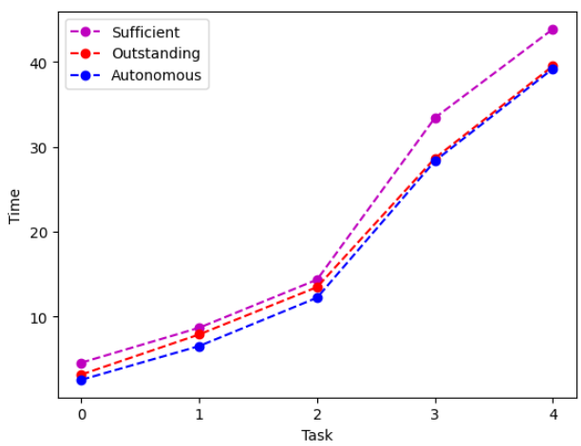
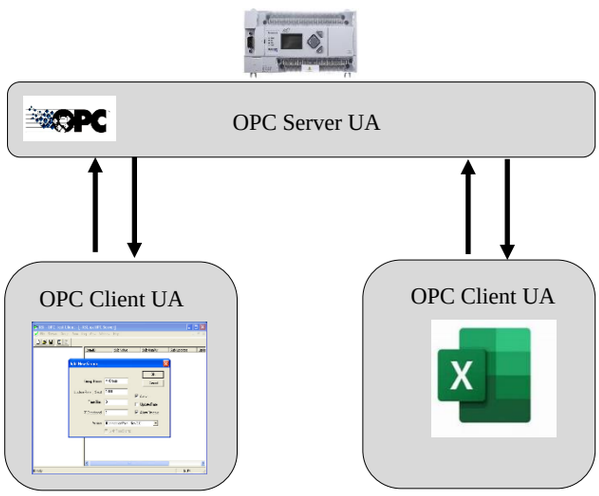


Figure 4 Performance series task

The timestamps and performance rates are sensitive to time-based information and exhibit the trend of the student's skills. The evaluation sequences describe past, present, and future features that capture long-term deendencies of time series data **(Nguyen et al, 2020)**.

For example, a sufficient-level class requires more time to implement control tasks versus the outstanding and autonomous levels. Additionally, the outstanding-level and autonomous-level classes exhibit similar performance indices. However, there is a trend in the time window markers to classify each area.

Dataset creation (2) transfers the timestamps into a database format through an OPC server (Object Linking Embedded for Process Control Server) communication provided by RSLinx OPC Server. An OPC server is object-model-based distributed software that enables direct connection with the PLC variables with data handling interfaces, reducing complexity in data capture and management **(Ahmad et al 2020).** The Figure 5 shows the communication scheme between PLC and the data interface.



The distribution of test sequence data was divided into 200 samples for each category: sufficient, outstanding, and autonomous, to obtain an initial dataset of 600 test sequences

stored in CSV format. The deep-learning model uses the Dataset for the training and validation stages. Each feature corresponds to the completed time of the task. The table shows the design of the randomized dataset.

Record	Inputs					Outputs
1	T0	T1	T2	T3	T4	Sufficient
..	T0	T1	T2	T3	T4	Outstanding
600	T0	T1	T3	T3	T4	Autonomous

Table 3 Dataset structure

The deep learning LSTM model (M1) (3) assesses the student based on performance features over time in solving tasks. Typically, multi-label classification problems use recurrent sigmoid activation **(Lipton et al, 2015)**, and LSTM models have demonstrated high accuracy in multivariable classification **(Soufiane et al, 2021), (Xiao et al, 2020)**. The design of the model M1 presents a sigmoid recurrent activation function and five layers. The input layer presents a hidden layer with 64 LSTM neurons (tanh activation). In the middle, hidden layers use 64 LSTM neurons (SoftMax activation) and dropout layer at 20%. Finally, the output layer uses a SoftMax function. The Figure 6 illustrates the schematic of the proposed model in M1.

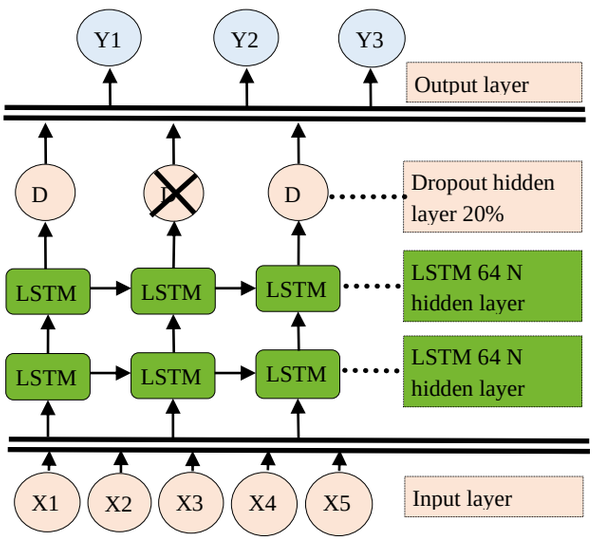


Figure 5 Model M1 structure

The behavior of the test sequences that students develop during the evaluation is from a non-linear nature, so a recurrent model of the LSTM type offers advantages in extracting series characteristics, as the mathematical model enables the LSTM cell to determine features of the previous state.

First, the model operates in the time state t**,** with the input set x**,** and the previous state h_{t-1}, to determine which information to retain or forget from the previous state f_t of the equation 21.

$$f_t = \sigma\left(W_{ij}h_{t-1} + W_{fx}x_t + b_f\right) \quad (21)$$

Where σ is la logistic function, W is the weight matrix, y b describe the bias of the network **(Jeong et al, 2019)**. Model M1 uses the highly efficient rates of SoftMax function in multivariate classification, specifically in the final layers of a recurrent LSTM network **(Arbane et al, 2023)**. The Equation 22 shows the mathematical expression to define SoftMax cross-entropy loss function.

$$\hat{Y} = \frac{e^{xi}}{\sum_{i=1}^{k} e^{xi}} \quad (22)$$

Where e^{xi} is the standard exponential function applied to the input value, k is number of classes, and $\sum_{i=1}^{k} e^{xi}$ ensures that the sum of the values results equals to 1 and that the values are within the range of (0 to 1). The Adam optimizer has an advantage as a multi-variable optimizer in LSTM classification problems.

The Adam algorithm uses adaptive gradients, which calculate the movement of gradient averages and squares to automatize the learning rate process **(Sakinah et al, 2019)**. A 20% dropout removes some neurons during training, which aids in the generalization of learning and helps prevent model overfitting. The training process uses 80 epochs and 80% of the samples for training, and 20% for validation.

An additional non-recurrent neural network model (M2) was developed to compare the results. M2 Model has 5 layers: the input layer, 1 hidden Dense layer with 64 neurons (Relu activation), 1 Dense layer with 64 neurons (SoftMax activation), 1 dropout layer at 20%, and the output layer. The Figure 7 shows the schematic of M2 model.

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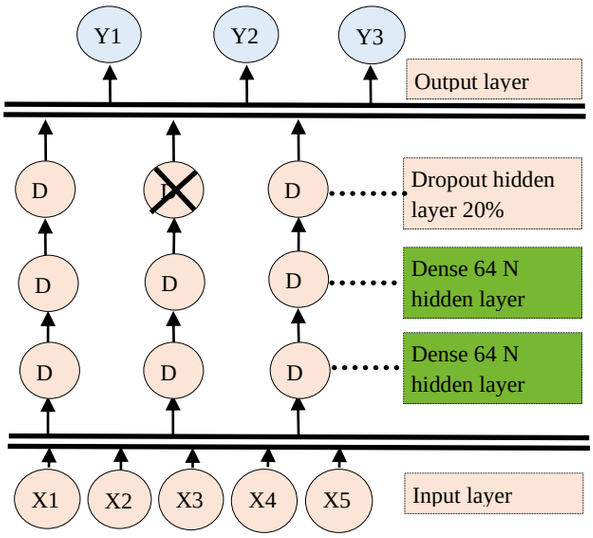

Figure 6 Model M2 structure

In M2 model, a SoftMax function was used in the last hidden layer, and a 20% dropout was applied for model response reliability. Additionally, it was optimized using the Adam algorithm in model compilation, and a training of 250 epochs was proposed for M2 model.

Model Evaluation

Several experiments evaluate the performance parameters of models M1 and M2. In the first level, the evaluation shows the overall performance percentages. The second level assesses the learning process in terms of time and graph characteristics. Finally, the confusion matrix shows the model error percentage.

Classification model performance

Typically, the parameters evaluated in LSTM models include accuracy and precision **(Althubiti et al, 2018).** Model M1 was compared with model M2 and two additional machine learning methods, Random Forest and KNN (K Nearest Neighbors). The table shows the results.

Method	Accuracy	Precision
LSTM – M1	91.70 %	92.40%
NN – M2	86.70%	88.30%
Random Forest	90.80%	90.10%
KNN	91.20%	90.54%

Table 4 Results model

The results show that model **M1** achieves a higher percent accuracy in determining whether the student is sufficient, outstanding, or autonomous in the test sequences. The results of **M1** versus **M2**, given the nature of the time-series input data, shows that **M1** achieves a higher accuracy and precision rate in learning while retaining the time-dependent characteristics of student performance.

Learning features

The evaluation of models **M1** and **M2** during the training and testing phases shows different behavior in the loss function and accuracy graphs. The figures 8 and 9 illustrate the behavior of the loss function for models **M1** and **M2**.

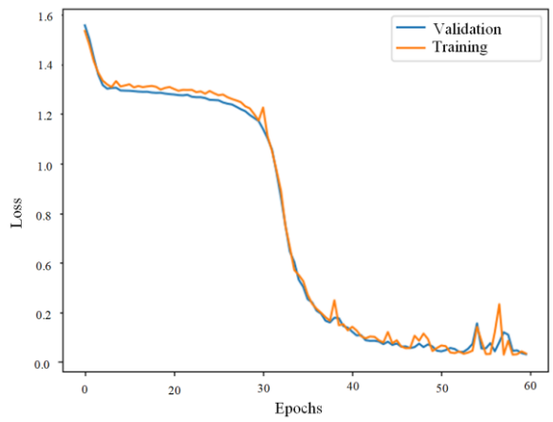

Figure 7 Model M1 Training and validation behavior

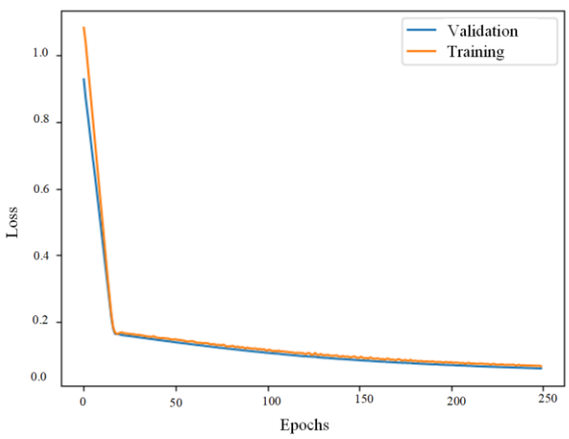

Figure 8 Model M2 training and validation behavior

The figure shows the performance of model M1 in terms of the epochs required to achieve an accuracy of 91.70% and a loss function below 0.1 after epoch 80. Model M1 exhibits the typical noise behavior introduced by the 20% dropout. The model M2 in the figure shows a smooth behavior; however, it requires more than 225 epochs to reach a stable level in the loss function and an accuracy level of 86.70%.

The accuracy behavior for models M1 and M2 is shown under the same epoch conditions, where it can be observed that model M1 requires fewer epochs to achieve the accuracy percentage. The figures 10 and 11 illustrate the accuracy function behavior for models M1 and M2.

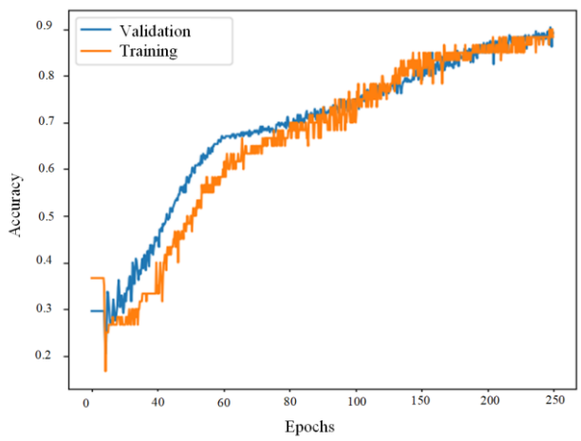

Figure 9 Model M1 accuracy behavior

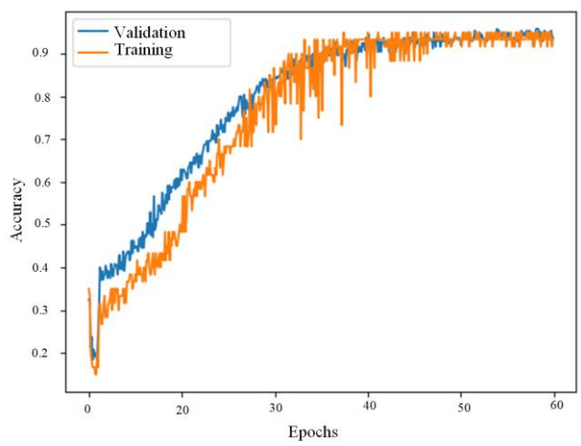

Figure 10 Model M2 accuracy behavior

The typical behavior of models associated with noise from a 20% dropout are shown in figures. The models get the accuracy percentages at different epochs. Model M1 gets its maximum accuracy at 60 epochs, while model M2 achieves it after 200 epochs.

Error evaluation

Usually, confusion matrices are used to determine the error of a deep learning model. **(Laghrissi et al, 2021).** The confusion matrix contains a summary of the predictions made by the classification model. The Figures 12 and 13 shows the confusion matrices for model M1 and M2.

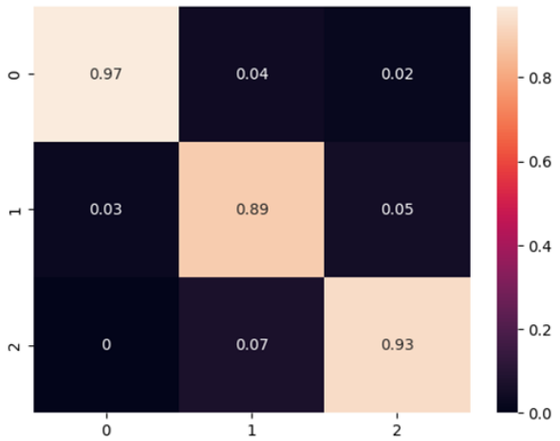

Figure 11 Model M1 confusion matrix

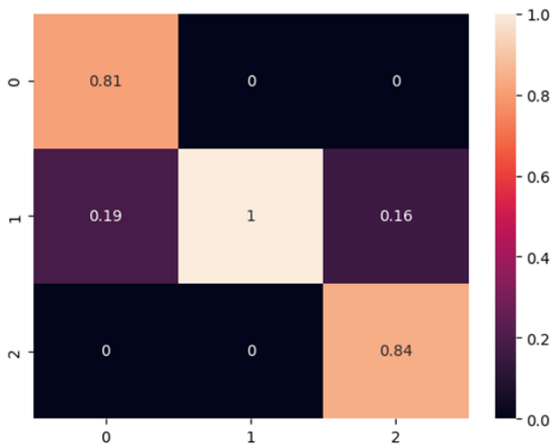

Figure 12 Model M2 confusion matrix

As seen in the Figure 12, model M1 has a higher error rate in identifying label 1 (outstanding), with a low probability of classifying it as 2 (autonomous). The highest accuracy rate is in label 0 (sufficient) and label 2 (autonomous). On the other hand, in the Figure 13, model M2 has the highest probability of making an error in label 0 (sufficient), and the highest accuracy rate is observed in label 1 (outstanding).

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Conclusion

This article presents a classification model for evaluating students' competencies in control tasks to determine whether the student is sufficient, outstanding, or autonomous in solving activities related to automation and control. At times, assessment through exams can lead students to memorize information to pass an evaluation. Therefore, this method demands knowledge and requires the student to demonstrate professional abilities. Therefore, this method demands knowledge and requires the student to demonstrate professional abilities. The present paper creates an assessment of students based on a time series trying to make a relation between theoretical knowledge and practical abilities. In conclusion, a certified student can master the theory in the practice competencies by improving task times.

Model M1 presents the following improvements in the evaluation process:

- Model M1, when compared to model M2, exhibits a higher accuracy and precision rate in classifying the labels of 'sufficient,' 'outstanding,' or 'autonomous'.
- Model M1 has a better learning process in terms of the number of epochs required to achieve an effective classification percentage.
- Model M1 has lower error rates in confusion matrices, making it less likely to classify students incorrectly.
- Model M1 is a tool that allows complementing the theoretical evaluation of students by linking practice to an AI system to determine the category associated with their performance.

Finally, the project begins as an assessment alternative for a specific zone within the field of automation and control. However, this article demonstrates an opportunity approach for its implementation in various areas associated with engineering. Nowadays, academic institutions have a big challenge in developing evaluation methods that evaluate beyond theoretical concepts and focus on certifying students' practical skills.

The results demonstrate high levels of accuracy and precision, thus promoting further research in future work to continue enriching the dataset and establishing data acquisition systems associated with IoT. It is necessary to preserve the dynamic data structures and the generation of robust datasets to use them in competence certification processes.

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Planned and impulsive buying habits and their relationship to life satisfaction in the staff of a higher education institution

Hábitos de compra planificada e impulsiva y su relación con la satisfacción con la vida en el personal de una institución de educación superior

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Abstract

Purchasing habits have become a highly relevant topic in the study of consumer behavior; healthy purchasing habits produce positive finances, but impulsive purchasing habits can generate adverse impacts on different personal aspects of consumers, such as over-indebtedness, sometimes reducing their well-being and life satisfaction. The objective of this study was to identify the planned and impulsive buying habits of the staff of a higher education institution, in order to establish whether there is a significant relationship with life satisfaction. The research was quantitative, descriptive and correlational, where three scales (attitudes and habits of planned purchasing, impulsive purchasing habits and life satisfaction) were applied to 101 full-time employees of a higher education institution. The main results were the identification of a high positive correlation between planned buying habits and life satisfaction, as well as the finding that there is no significant correlation between the variables life satisfaction and impulsive buying habits.

Habits, Purchasing, Impulse buying

Resumen

Hábitos de compra impulsiva pueden generar impactos adversos en distintos aspectos personales de los consumidores como el sobreendeudamiento mermando en ocasiones su bienestar y satisfacción con la vida. El objetivo del presente estudio fue identificar los hábitos de compra planificada y compra impulsiva en el personal de una institución de educación superior, con la finalidad de establecer si existe relación significativa con la satisfacción con la vida. La investigación fue de tipo cuantitativo, descriptivo y correlacional, donde se aplicaron 3 escalas (Actitudes y hábitos de compra planificada, hábitos de compra impulsiva y satisfacción con la vida) a 101 trabajadores de tiempo completo de una institución de educación superior. Los principales resultados fueron la identificación de una correlación positiva alta entre los hábitos de compra planificada y la satisfacción con la vida, así como el hallazgo que indica que no existe una correlación significativa entre las variables satisfacción con la vida y hábitos de compra impulsiva.

Hábitos, Compra, Compra impulsiva

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Introduction

Consumer behavior has undergone significant changes throughout history, nowadays digital media have made it easier for people to be more informed, which allows them to rationalize their consumption by being able to compare characteristics between different products such as price, quality, functionality, variety among others, on the other hand, a significant number of individuals tend not to rationalize their purchases a priori, according to data from the University of Nebrija (2022) more than 90% of purchasing decisions are made on impulse and involving emotions.

Rodríguez, Peña and Casañas (2020) citing Rook (1987) conceptualize impulse buying as an unplanned purchase that arises from a sudden and lasting sensation that originates an emotional conflict for the buyer; on the contrary, the planned purchase is defined as one that presents a high level of cognition and information, as well as a lower degree of emotions when making a consumption decision (Castellanos, Denigri and Salazar, 2020).

Denigri (2010) affirms that healthy purchasing styles produce positive finances and help to reduce impulsivity. For Zhao et al. (2021), one of the main consequences of impulse purchases is indebtedness; people who consume impulsively use credit cards excessively on most occasions, considering them an easy-to-use, safe, fast and efficient means of payment that satisfies their desire to obtain a product or service, a statement that coincides with that mentioned by Cavazos, Lagunes and Melchor (2023) who state that the indebtedness caused by the use of credit cards occurs due to various factors such as special promotions, the income level of consumers, but also for other reasons such as the pleasurable sensations caused by impulse purchases, generating long-term impediments to make debt payments.

According to Diaz, Sosa and Cabello (2019) access to consumer credit has increased considerably in recent years, mainly the use of credit cards which rose by 62% from 2011 to 2018, information that is complemented by the information provided by the National Survey on Household Finances (ENFIH 2019) which showed that 53.8% (19.7 million) of households in Mexico have non-mortgage debt derived from consumer credit such as personal loans, payroll and credit cards. The easy access to personal financing produces the opportunity to acquire a greater amount of goods and if an adequate purchase planning is not established, it can lead to over-indebtedness.

On the other hand, Bashar and Pathak (2023) state that impulse buying has become one of the most relevant aspects for companies because it contributes significantly and profitably to their financial performance. While it is true that impulse purchases trigger higher sales and returns for companies, it is possible that they have an adverse impact on different aspects of consumers' lives, such as their well-being and life satisfaction.

Satisfaction with life is defined as the perception of the quality of one's own experiences; it is a variable that indicates internal well-being, studied on the basis of the individual's own assessment Watanabe (2005).

Sepúlveda, Denegri, Echeverria, Jurghen and Paillao (2022) conducted an investigation on the effect of indebtedness on the mental health and subjective well-being of students, obtaining as a result that indebtedness is a significant predictor of life satisfaction. Castellanos et al. (2020) conducted a study in the Chilean student population where they identified an inverse relationship between impulse buying and life satisfaction, in the same sense Godoy, Araneda, Diaz, Villagrán and Valenzuela (2015) identified a direct positive relationship between rational buying habits and conservative attitudes with life satisfaction.

There are several studies that relate purchasing habits with consumers' life satisfaction in different regions of Latin America, such as Chile and Colombia. In the case of Mexico, research on these topics is limited, which is why the research question is posed:

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Is there a significant correlation between planned and impulse buying habits and life satisfaction in a sample of workers of a higher education institution in Sonora, Mexico?

Objectives

To identify the planned purchasing habits of the personnel of a higher education institution, with the purpose of establishing if there is a significant relationship with life satisfaction.

To identify impulse buying habits in the staff of a higher education institution, in order to establish whether there is a significant relationship with life satisfaction.

Methodology

The type of research is quantitative, descriptive and correlational, with a non-experimental design since the attitudes and buying habits as well as the satisfaction with life of the respondents are observed in their natural state after being analyzed, it is transversal since data are collected and the variables are analyzed in a single instant of time.

The method used to obtain data is the habits and attitudes scale. Attitudes are related to the way of behaving that are maintained around the variables they refer to (Fernández and Baptista 2014). For the present study, two scales measuring attitudes and habits of planned and impulsive buying were applied. To identify planned buying habits, the instrument "buying habits and behaviors" designed by Denegri, Palavecinos, Ripoll and Yánez (1999) was used, which consists of 13 items; for the measurement of impulsive buying, the scale developed by Revilla, Acosta and Reyna (2013) was applied, which is composed of 8 items. The reliability of the instruments was determined from a pilot test with a total of 140 university students obtaining a Cronbach's alpha of 0.807 for the purchasing habits and behaviors scale and 0.863 for the impulsive buying scale which indicates a good level of consistency being higher than 0.70 Zambrano et al. (2014).

In addition, the life satisfaction scale composed of 5 items designed and validated by Diener et al. (1985) was applied, the responses of all the instruments are Likert-type with five options ranging from Strongly agree = 5, Agree = 4, Indifferent = 3, Disagree = 2, Strongly disagree = 1.

The sample was determined by the convenience of the research and is composed of 101 employees from the academic and administrative departments (See Table 1).

Departament	Frequency	%
Academic	51	50.5
Administrative	50	49.5
Total	101	100.0

Table 1 Department to which they belong
Source: Own elaboration

The process for data collection and processing consists of the following steps.

1. Written authorization request to the university authorities for the application of the instrument.

2. Application of the scales via e-mail to academic and administrative personnel.

3. Data capture in SPSS version 23 statistical software.

4. Descriptive analysis of the data and obtaining Pearson correlation tests and interpretation.

Results

Descriptive statistics, mean and standard deviation were obtained for each of the scales. Table 2 shows that in the purchasing habits and behaviors scale, where reference is made to planned purchases, the highest mean response was for the item "select products according to their quality" and the lowest was for the item "If you buy clothes, read the label to know the characteristics and care required", the highest response mean was for the item "select products according to their quality" and the lowest was for the item "If you buy clothes read the label to know the characteristics and care required", in general, the practice of planned purchasing habits and behaviors is at a level ranging from medium to high, obtaining response means close to 4 in all items.

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Item	Media	Deviation Standard
1. You make a list of the products and services you need to purchase.	3.98	1.233
2.You select products according to their quality.	4.21	1.042
3. To distribute your money, order the products according to their importance before purchasing	3.91	1.234
4. Select products according to their price	3.84	1.181
5. Compare prices between different brands	4.16	1.111
6.Compare prices in different sales outlets.	3.72	1.234
7. Read product labels	3.52	1.277
8. Look at the net weight of the products	3.49	1.354
9. Ask about the warranty period of the products	3.67	1.281
10. Ask questions to the seller before buying	3.66	1.298
11. Plan your shopping in advance	3.98	1.104
12. If you buy clothes, read the label to know the characteristics and care required.	3.24	1.379
13. Examines in detail the products you buy	3.79	1.107

Table 2 Descriptive statistics of the scale "Purchasing habits and behaviors".
Source: Own elaboration

In the impulsive buying scale, the item with the lowest mean response was "the phrase "I buy first and think later" describes me well" and the highest was "I often buy things spontaneously". In general, the practice of impulsive buying habits was located at a medium to low level by obtaining means lower than 3 in all the items of the instrument (See Table 3).

Item	Media	Deviation Standard
1. I often buy things spontaneously.	2.92	1.238
2. The phrase "Right now" Describes the way you buy things.	2.30	1.063
3. I often buy things without thinking	2.12	1.177
4. If I see something I want, I buy it	2.68	1.232
5. The phrase I buy first and think later describes me well.	1.85	1.244
6. Sometimes I'm a bit foolish in my purchases.	2.18	1.203
7. I buy things according to how I feel at the moment	2.24	1.320
8. Sometimes I am a little reckless with what I buy.	2.14	1.209

Table 3 Statistics "Impulsive buying" scale
Source: Own elaboration

For the life satisfaction scale, the descriptive statistics indicated that the best evaluated item is "I am very satisfied with my life", and the item evaluated with the lowest mean number of responses is "In most aspects my life is the way I want it to be". This indicates that the respondents are very satisfied with their life, but they also consider that there are aspects in which they would like to improve (See Table 4).

Item	Media	Deviation Standard
1. In most respects my life is the way I want it to be.	3.61	1.029
2. My life circumstances are very good	3.82	.953
3. I am very satisfied with my life	4.05	1.043
4. So far I have gotten out of life the things I want.	3.77	1.103
5. If I could live my life over again, I would change almost nothing.	3.80	1.149

Table 4 Statistics scale "Satisfaction with life".
Source: Own elaboration

Pearson's r coefficient was applied to determine the existence of a significant correlation between the dependent variable life satisfaction and the independent variables planned purchasing habits and behaviors and impulsive purchasing habits.

Between the planned purchasing habits and behaviors variable and the life satisfaction variable, it is affirmed with a confidence level of 99% that there is a highly significant direct correlation by obtaining a significance level of less than 0.01, which indicates that to a high degree practicing planned purchasing habits and behaviors improves life satisfaction (See Table 5).

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		Purchasing habits	Satisfaction with life
Planned purchasing habits and behaviors	Pearson correlation	1	.416**
	Sig. (bilateral)		.000
	N	101	101
Satisfaction with life	Pearson correlation	.416**	1
	Sig. (bilateral)	.001	
	N	101	101

Table 5. Pearson correlation between life satisfaction variable and planned purchasing habits and behaviors variable.*Note: Correlation is significant at the 0.01 level (bilateral).
Source: Own elaboration

When Pearson's r test was applied to the variables life satisfaction and impulsive buying habits, it was determined that there is no significant relationship between both variables, obtaining a bilateral significance value of .052 greater than 0.05, which indicates that life satisfaction is not significantly influenced by the practice of impulsive buying habits (See Table 6).

		Satisfaction with Life	Impulsive buying
Satisfaction with life	Pearson correlation	1	.194
	Sig. (bilateral)		.052
	N	101	101
Impulsive buying habits	Pearson correlation	.194	1
	Sig. (bilateral)	.052	
	N	101	101

Table 6 Pearson's correlation between life satisfaction variable and impulse buying habits variable
Source: Own elaboration

Discussion

The results obtained in this research indicating the existence of a direct positive correlation between planned purchasing habits and behaviors and satisfaction with life, coincide with the findings made by Godoy et al. (2015) in the study of Satisfaction with life, attitudes towards purchasing and attitudes towards indebtedness in the city of Temuco Chile, where they identified that a high level of satisfaction with life is directly related to rational purchasing habits.

A contrasting result is that there is no significant correlation between impulsive buying habits and life satisfaction identified in this study, in the Chilean research it was determined that a low level of the variable life satisfaction has a negative correlation with attitudes towards impulsive and compulsive buying.

Conclusion

With the results obtained, it is concluded that the objectives of identifying the planned and impulsive purchasing habits and behaviors of the personnel of an institution of higher education and their relationship with life satisfaction have been met. The most relevant finding is the identification of a high positive correlation between planned purchasing habits and life satisfaction, which allows establishing recommendations in this regard. One of the recommendations is to carry out specific actions to encourage the staff of the higher education institution to improve their purchasing habits, such as courses on the proper use of credit cards, promotion of savings, as well as providing information on the influence of emotions on purchasing decisions. In addition, it is suggested to open new lines of research related to this topic, such as the analysis of the relationship between purchasing behavior and investment behavior.

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Improvement of the production scheduling for the casting line in a manufacturing company

Mejora de la programación de la producción de la línea de fundición en una empresa manufacturera

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Abstract

The present study was developed in a manufacturing company located in a Southern region of the state of Sonora, Mexico, and it is focused on setting forth a proposal for scheduling production in their casting line. The subject of study is a level of usage below desired, directly affecting the completion of production orders and, as a result, incurring in failure to deliver on time. The organization requires a tool to know the number of items it can produce and the required time to achieve production of the same. Thus, a technological solution for scheduling production was proposed to schedule production based on the equivalent unit's method. The results indicate that the company, when effectively using resources for the planning horizon, may execute orders by means of a tool that allows having formal and available information for decision-making.

Production schedule, Technological solution and, Equivalent units' method

Resumen

El presente estudio se desarrolló en una empresa manufacturera ubicada en una región del sur del estado de Sonora, México, y está enfocado a plantear una propuesta de programación de la producción en su línea de fundición. El objeto de estudio es un nivel de utilización por debajo de lo deseado, afectando directamente el cumplimiento de las órdenes de producción y, como consecuencia, incurriendo en fallas de entrega a tiempo. La organización requiere de una herramienta que le permita conocer el número de piezas que puede producir y el tiempo necesario para alcanzar la producción de las mismas. Así, se propuso una solución tecnológica para programar la producción basada en el método de la unidad equivalente. Los resultados indican que la empresa, al utilizar efectivamente los recursos para el horizonte de planeación, puede ejecutar órdenes mediante una herramienta que permite contar con información formal y disponible para la toma de decisiones

Programación de la producción, Solución tecnológica, Método de unidades equivalentes

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Introduction

One of the elements that companies must consider in planning a productive system is that of its production capacity. Chase and Jacobs (2014) define capacity as "the amount of production that a system is capable of generating during a specific period", that is, it has to do with the number of items that are produced in a shift, day, week, etc. According to Krajewski and Ritzman (2000), capacity is classified into different categories: maximum capacity, nominal capacity, and actual capacity. The actual capacity of a production process is what determines if the resource is enough to fulfill the demand; it is the most widely used when production is scheduled. In the computation of actual capacity, normal conditions such as downtimes, environmental conditions, unforeseen situations, or the absence of staff are taken into consideration, just to mention a few.

The two main concerns regarding production scheduling are the "priorities" and the "capability" (Wight, 1984). An incorrect scheduling leads to important effects on the operations side, such as the lack of efficiency, productivity, and harnessing of raw materials, which impacts on production costs (Romero et al., 2004). Thus, companies need to start a path of continuous improvement by implementing a correct production scheduling system (Alvarez et al., 2004). "Unfortunately, many producers have inefficient production scheduling programs" (Herrmann et al., 2007). In most cases, production scheduling is done empirically based on the experience of a workgroup (Berruto et al., 2006). In addition, in most food processing industries, and many related technology centers, there is a lack of technical and managerial labor that is familiar with simulation and optimization methods (Banga et al., 2003).

On the other side, schedules produced by information systems may help manufacturers improve deliveries, timely respond to customer orders, and create realistic schedules (LaForge and Craighead, 1998). Even so, "the greatest difficulty does not reside in the scheduling itself, but in its implementation" (Alvarez et al., 2004).

In the company under study, production scheduling is carried out informally and requires the development of computational tools to have better control in organizing customer orders in the casting production line. It is not a priority to diminishing costs nor expanding the line capacity, but to be able to produce customer orders on time. The current situation does not allow that production managers know what is being produced at a given time, and the date when delivery to the customer is feasible. There are several elements involved in the complex decision making, such as materials, equipment, labor, facilities, processes, and it becomes more complex as the demand, the number of products, and the number of customers, increase. How products are manufactured in the casting line may be an aspect that influences this complexity, as it has several workstations where product dimensions make manufacturing times vary. Given the above situation, how many different-sized products may be manufactured with the available resources? and how much time is required to comply with the delivery time agreed with the customer? The answers to these questions require considering different variables, and this problem is addressed in the present work proposing a computational tool to solve it. The objective of this research is to show a technological solution for production scheduling in the casting line of a company, based on the equivalent unit method, to in-crease both the production rate and the fulfillment of customer orders.

Implementing a production scheduling proposal using computer software enables correct manufacturing of production orders, generated by customer orders, allowing for greater efficiency. By allocating a correct distribution of time to manufacture the production orders, the equipment in the casting line will decrease its sub-utilization. A more efficient production scheduling leads to higher levels of service, improving customer satisfaction, and efficient use of resources. Information regarding production times of incoming orders in the casting production line will be readily available for the production manager, who may therefore watch delivery times. Besides, the manager will be able to adapt to production variations by knowing the productive horizon in the casting line based on future production orders.

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Background

Technological advances and the demand for highly customized products have forced manufacturing companies to adapt and develop new solutions to become more dynamic and flexible to cope with changing markets. Companies must adopt modern methods, techniques, and tools based on the planning and integration of production processes, value analysis, and follow-up and control methods for manufacturing orders, to reduce their production costs (Filip, 2018). In this highly competitive scenario, production scheduling plays a fundamental role in ensuring that all operations and processes are executed on time in the company (Alemao et al., 2021, Frazzon et al., 2018).

Production scheduling determines the launching of manufacturing orders and the sequence of operations (Gonzalez, 2005), while in the master production schedule the number of final items that will be produced during specific periods is detailed (Krajewski and Ritzman, 2000). Production scheduling specifies the future times to execute production events (Maynard, 2005). In addition, it can be said that production scheduling is an activity that consists in determining production plans and schedules, according to the operation priority, and therefore determining start and completion times to achieve the maximum level of efficiency (Pajuelo Flores, 2001). The objective of production scheduling is to determine when production orders will start being processed. The process consists of determining the times to conduct production activities, and then adapt the schedule to the production plan, and at the end support the decisions and actions to accomplish the desired production objectives (Maynard, 2005). It is advisable that, in a flexible system, the periods within a production schedule be short-term, by weeks or days. The company under study is a company in the industrial manufacturing sector transforming raw materials into end products using machinery, labor, and tools. There are two main characteristics of the make-to-order system for this company: the demand is variable and the production system is highly organized, to fulfill orders and comply with customer requirements in the right time and manner.

Some companies still regard production as a residual activity, eminently technical, and lacking strategic perspective, with concrete objectives to be accomplished, and whose entire responsibility relies only on the plant managers (Becerra et al., 2008). Today, there are multiple and, in some cases, complex production scheduling techniques. Among the techniques based on operations research, some aim to the optimization of the company resources, seeking the maximum or minimum value of an objective function, subject to certain constraints with a defined number of variables (Herrera, 2011). Berruto et al. (2006) propose a production scheduling optimization method based on a two-step optimization procedure using mixed-integer linear programming. Berruto et al. (2006) show the challenge of planning in a bottling plant, highlighting that in this industry a considerable amount of time is required in production planning and that planning is highly influenced by demand seasonality and numerous types of containers required for distribution.

The proposal of Romero et al. (2004) presents a case study for a company in the construction sec-tor, in which it was determined that through a design for production scheduling it is possible to optimize the allocation of raw materials to process a customer order. Alvarez et al. (2004) proposed operation scheduling in wood furniture manufacturing through Theory of Constraints, pointing out the importance of leveraging production by a comprehensive usage of the installed capacity. Chergui et al. (2018) analyze the planning, nesting, and scheduling problem in additive manufacturing. The mathematical formulation of the problem is presented, and a heuristic approach in Python is proposed to solve it. The objective of their proposal is to satisfy the requests received from different customers, distributed by expiration dates. Frazzon et al. (2018) show a hybrid approach to integrate scheduling of production and transportation processes combining mixed-integer linear programming, discrete event simulation, and a genetic algorithm. In the proposal of Filip (2018), tools focused on production scheduling and efficient management of the manufacturing cycle in the company are presented, as well as the decision tree method as a technique to improve decision-making activity for the launch of a new product.

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Salamanca Leguizamón et al. (2009) conducted research in which a heuristic method was proposed for solving the problem of sequencing flow shop systems with unlimited buffers to minimize the make span. Using the proposed method, there were better responses compared to the FIFO (First In, First Out) rule, LPT (Longest Production Time) rule, SPT (Shortest Production Time) rule, and the Palmer heuristic method, for the make span, flow time, average flow time, percentage of machinery utilization, percentage of machine idleness, total waiting time, and average waiting time indicators. Petrovic et al. (2016) uses the method based on the particle swarm optimization algorithm and chaos theory to propose solutions to problems related to planning and programming processes. The optimal scheduling plans presented by Petrovic et al. (2016) are obtained through multi-objective optimization of production time and cost. The optimal scheduling plans are generated with three objective functions: interval, balanced level of machine utilization, and mean flow time. Hubbs et al. (2020) examine the application of deep reinforcement learning to a chemical production scheduling process considering uncertainty. Hubbs et al. (2020) model achieves dynamic programming by comparing the results with a mixed-integer linear programming model (MILP) that schedules each time interval on a receding horizon. Cheng et al. (2015) consider an integrated production and distribution scheduling problem for manufacturers. The objective function presented by these authors is to minimize the total cost of production and distribution for the manufacturer. An ant colony optimization method is proposed to solve the production stage and a heuristic method for the distribution stage.

In the project by Pajuelo Flores (2001), it was concluded that estimated times and the constant follow-up of new or special products to estimate the creation at process and bottling levels are key to obtain the desired results. The application via software used was the Excel database, but it was determined that there are other alternatives to scheduling, such as Access and Microsoft Qry.

The author mentions that the use of equivalent system units, as implemented in his project, may also apply to manufacturing companies, and although each situation is different, there should be no reason for the basic report criterion to vary; it would only modify how information is required for production line being analyzed.

There are some reports on the application of scheduling tools to real situations. For example, Ferro et al. (2021) apply discrete event simulation software to optimize the production planning of a company in the textile sector in Brazil. Also, Micieta et al. (2021) developed a dynamic production scheduling system and they tested it on fictitious data but al-so in data coming from a company that produces railway wagons and bogies. Although García-Menéndez et al. (2021) apply their methods to randomly generated instances, the production environment described by them corresponds to a real steelmaking process flow.

The present article presents a technological solution for scheduling the production of decorative items in the casting line of a manufacturing company.

Methods

The case study is a company in the Mexican manufacturing sector that works using a make-to-order (pull) production system. The products are frames for mirrors and paintings, and decoration items, all produced by reaction-injection molding of polyurethane resin. Once the production starts, the reactions are heated and mixed to be injected into molds. After cooling, the units are separated from the molds, sent to finishing processes, and assembled with mirrors or paintings. The final assembled product is packed for shipping to the customer.

The methodology is based on the Index Method (Garcia-Menendez et al., 2021), adapted to the project, because it provides backward scheduling, which means that it calculates the number of pieces that must be produced from the last day of the stipulated time until day zero of the production, to complete the production on time, using the real capacity of the production line.

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For the development of the project, the following materials were used:

- Company sales catalogs of the different models. It was used to classify the items by size.
- A 10-meter flexometer. It was used to obtain the sizes of the items which were not in the catalogs, to classify them by sizes accordingly.
- Registry tables. Results obtained for the standard times were registered here.
- Chronometers. These were used to measure the total standard times, per item size, in each station.
- Minitab version 17. It was used for data analysis, normalizing casting line process times, and obtaining statistical information from the process.
- Student t-distribution Table, to obtain the corresponding sampling formula value.
- Company sales registries to calculate the actual line capacity.
- Casting line production registries to calculate the actual line capacity.

Determination of the standard average times per size

The classification of the items was done with help of the catalogs that are managed by the Sales area, for the years 2012 to 2018, identifying visually the items and their dimensions. Some of the items in the catalog were no longer produced, so at first, an audit in the molds area revealed which ones were no longer produced, doing a register of this. After that, a comparison of the molds catalogs was made to have a reference of the limits of the size by item. For the classification, those items with more demand were selected to determine which were small, medium, and large. The classification in sizes was based on the press used for the production.

A pilot test was carried out for each class (small, medium, large) to measure the standard times. The method to register times was based on the technique of back-time-to-zero, because the chronometer started measuring when the material started processing in the station. There was a continuous cycle because the chronometer stopped until the material was unloaded and stored in the rack. All the times were registered in paper worksheets. With the data obtained, Minitab was used to calculate the appropriate sample size according to the formula (1):

$$\mathbf{n} = \left(\frac{t*S}{E*\bar{x}}\right)^2 \quad (1)$$

Where:

t= value corresponding to the Student´s t-distribution (with 90% confidence level, t=2.064)

S= Standard deviation of standard times

E= percentage error (10%)

x=standard time average value

n = size of the sample

After applying the formula, the results indicated that it was necessary to collect additional standard times. For every size, 25 samples were obtained initially. According to the results of the formula, 25 data were required for large size items, 32 data were required for medium size items, and 39 data were required for small size items. The difference to 25 was the number of additional time data required. These samples were measured again in the casting line, and the results were added to the worksheet in Minitab 17.

Evaluation of the real production rate in the casting line

With data are drawn from sales and monthly production registries in the casting line, a comparison was conducted to know the actual production rate and how information is handled within the company. Production is registered monthly, and sales are registered daily. Some differences were found, indicating an inconsistency in the data between the records of the departments of Sales, Production planning, and the Production line.

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Scheduling proposal using the equivalent unit method

An Excel file was created with all the information on the standard times per item according to its size, percentage of units, equivalent units, and equivalent production, as shown in Table 1.

Production	Units produced	Cycle time (Hrs)	Equivalent units	Production equivalent units
Small	19	0.53	1.0392	12
Medium	24	0.51	1.0000	14.4
Large	30	0.68	1.3333	24
Total	73		3.3725	50

Table 1 Initial date
Source: own elaboration

Once that information was obtained, the sequencing method was developed based on equivalent units. After that, the planning horizon that will be taken into account to conduct the production scheduling was determined. Then, the sequencing method was applied by using the planning horizon and the actual capacity in the production line, which led to the overall sequencing logic together with the use of macros to design the main window and its respective buttons. Table 2 shows the production plan of one day, but it must be developed for each day of the planning horizon, linked to the data in Table 1 to follow up the method. In this way, the overall sequencing logic can be integrated using macros as will be shown in the homepage window and its respective buttons.

Total Day 1	Production	UE	Total UE	Factor	Prod UE	Prod Real	Gap
100	Small	1.0	104	0.244	16	16	84
55	Medium	1.0	55	0.129	9	9	46
200	Large	1.3	267	0.626	42	31	169

Table 2 Planning horizon
Source: own elaboration

Identification of improvements and corrections using a pilot test

Once the scheduling software was ready, a pilot test with a previous production order from the strongest customer was conducted, to simulate a more realistic situation of the casting line scheduling. Data from past orders were used in the Excel file to see the behavior of the proposed schedule. The operation of the Excel file was presented to the managers of the company to obtain their feedback, making some amendments to the software.

Results

Table 3 presents the dimension limits to classify items by size. As a result, a catalog was created in which the produced items can be found according to their size: small, medium, and large.

Height Dimensions	Width Dimensions	Classification
60 cm – 110 cm	95cm - 120cm	Small
94cm - 113cm	121cm – 159 cm	Medium
93cm - 114cm	160cm - 216cm	Large

Table 3 Dimension limits for size classification
Source: own elaboration

It was decided that the pilot time-keeping test run 25 times per item size, adding a total of 75. Times were entered in a Minitab 17 database to obtain the missing data for the sampling size formula, which is the average cycle time value and the standard deviation (see Table 4).

Size	Average Cycle time per item (min)	Standard Deviation
Small	31.73314667	9.637632124
Medium	29.8760336	8.149762866
Large	40.619704	9.78443599

Table 4 Cycle time averages and standard deviation per item size in pilot test
Source: own elaboration

Medium-sized items exhibit less time because they are the ones which are produced the most, and operators have better control of the molds and how they must be worked; longer times appear for the large items because the molds are heavier and it is more com-plicated to have control over the same. On the other hand, when small items are worked, they normally do not have a high priority, which results in operators not taking the molds out of the presses, thus extending the cycle time and obtaining the following times ac-cording to each size:

- Larger items take an average of 0.68 hours to complete the cycle.
- Medium-sized items take an average of 0.51 hours to complete the cycle.
- The small items take an average of 0.53 hours to complete the cycle.

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The times per station were used to determine the unproductive time for each of the three item sizes. An average time per station sum was carried out (see Table 5) which was considered as the productive time, and afterward, it was subtracted from the cycle time. The results are presented in Table 6, Unproductive time in minutes per item size. The presses are scheduled for ten minutes, regardless of the size of the mold; this is the time it takes the polyurethane to correctly react and reduce the possibility of defects in the end product.

Size	Station 1	Station 2	Station 3	Station 4	Station 5
Small	2.012	2.790	2.399	10	2.964
Medium	4.057	3.285	2.651	10	2.639
Large	4.481	5.531	3.064	10	4.378

Table 5 Average time in minutes per station
Source: own elaboration

Size	Productive Time	Cycle Time	Unproductive Time
Small	20.966	31.805	10.884
Medium	22.633	30.753	8.119
Large	27.468	40.619	13.151

Table 6 Unproductive time in minutes per item size
Source: own elaboration

The main time factors involved in how long it takes the operators to work a mold are their weight, and production priority. Medium-sized items normally have a high pro-duction priority, but due to their weight, it takes longer to arrange the molds in the stations; the small items remain at a mid-point due to priority.

The next step was to have reliable data regarding the actual casting line production. To achieve this, the production logs that the production administrator had from previous months were used (See Table 7). These logs do not specify the size of the item that was produced; therefore, the casting line station operator's logs were taken into consideration to verify the information. The operator's log is created from the production orders provided by the administrator, and it is here where the item is annotated before it goes into the press. That is how the number of items per average size that are produced daily. (See Table 8).

Month	Days worked	Total items	Daily average
February	19	1345	71
March	19	1759	93
April	21	1260	60
May	22	1934	88
June	21	1277	61
July	22	1527	69
August	22	1502	68

Table 7 Production administrator's monthly casting line production log
Source: own elaboration

Item Size	Darly Production Percentage	Daily Production Average
Small	26%	19
Medium	33%	24
Large	41%	30

Table 8 Log of items by size produced daily in the casting line injection station
Source: own elaboration

The information provided by the production administrator's log made it possible to know that, on average, 73 items may be produced daily, and according to the injection station, 41% of production are large items, reflecting a greater production demand, and those of least de-mand are the small items, representing 26%.

To develop the production schedule proposal, it was necessary to start by finding a plat-form that, based on the company's computing equipment capabilities, could schedule the equivalent unit method. It was decided to use Microsoft Excel because, by using macros and Visual Basic, it was possible to develop a sequencing method with the fluency and professionalism of specialized software. The sequencing program is shown in the following screenshots (See Fig. 1), in which follow-up is given to production order scheduling.

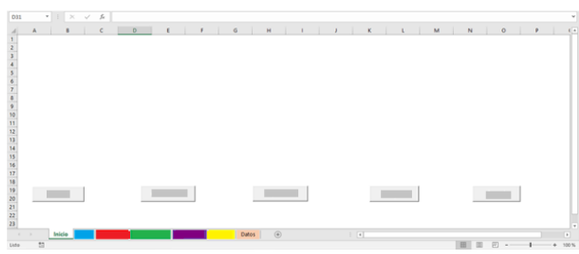

Figure 1 Homepage Screen
Source: own elaboration

Figure 1 shows the Homepage screen, and in the lower part of the same, some but-tons give access to the order capture window. The worksheet of each color will be used to capture and process the scheduling for each order.

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Figure 2 shows the order capture window which resulted from clicking on one of the buttons for the corresponding customer. This window contains sections to enter the number of units to be produced according to their size.

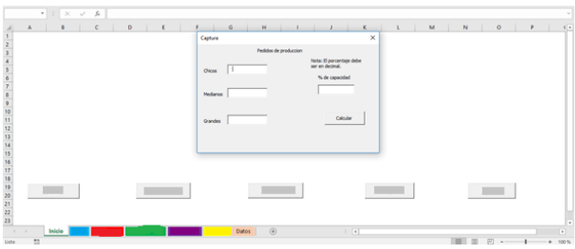
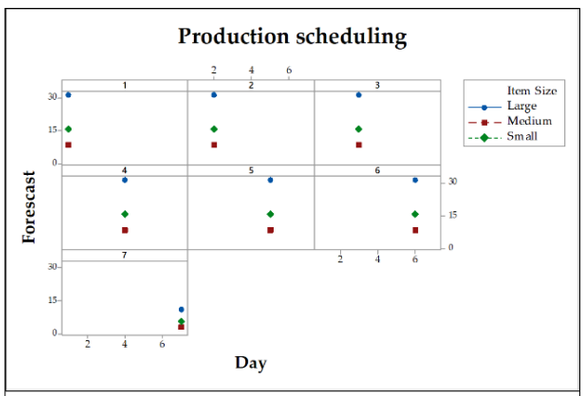


Figure 2 Order Capture
Source: own elaboration

In addition, there is a section in which the dedicated capacity percentage of the mentioned order can be set.

The objective is to have several production orders that are executed with different capacities, which will directly reflect the time it takes for orders to be completed. To conclude the order capture process, the calculate button should be clicked. (See Figure. 3).



Item Size	Total items	Items per day	Delivery policy	Capacity	Dedicated production
Small	100	16	6	80%	
Medium	55	9	6	80%	
Large	200	31	6	80%	

Figure 3 Order contents
Source: own elaboration

Figure. 3 shows the results of production scheduling by sequencing. In the upper part of the figure, there is a summary of the scheduling where essential information is shown for decision-making. The contents of the order may be appreciated, the items per day that have to be produced, and the delivery policy that was handled for such order; the policy will be based on the percentage of dedicated production.

On the scheduling table (See Figure. 4) a planning horizon of 20 days may be appreciated. In such a table the daily production of each model will be reflected, as well as the day in which production will be concluded.

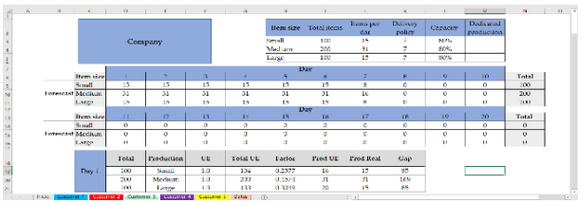


Figure 4 Daily Description
Source: own elaboration

In Figure. 4 there is a detailed description of daily scheduling. As the page is scrolled down, the necessary days to execute production can be observed; the description shows the sequencing procedure either by the indexes or the equivalent units method. Moreover, it has drop-down menus to incorporate special orders within the scheduling process.

Discussion

Among the improvements obtained with the solution concerning what was available before its implementation, the following could be mentioned: Production was increased when suggestions were given on the required time to manufacture each of the products. There was formerly an average of 72 daily items processed, and currently, there are 90 items manufactured, which leads to an improvement of 25% in the process efficiency. This was possible without investing in any equipment, hiring staff, or making changes in the production line. This efficiency will increase as long as there is a better usage of resources, resulting in being able to process more orders or cover less time in the processing the same, which leads to increased production capacity.

Another benefit obtained was the fact that, at any given time, knowledge of the time required for product manufacturing is available at any moment; the data allows determining production priority to fulfill customers' orders, and guarantee satisfaction.

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The main contributions of the project for the company were the improvement of the production rate and the organization of their production scheduling activity. The first one helps to meet the delivery dates required by the customers, or at least allows promising more realistic due dates. The second one establishes a baseline to implement more complex algorithms to reduce makespan or setup times, or to reduce backlog in the future.

Conclusion

It was possible to achieve a proposal oriented towards meeting the needs in terms of production scheduling, which also helps create production mixes per item, and determine what capacity percentage will be dedicated to each incoming order.

The proposed production scheduling for the company under study will allow them to know delivery times and the number of items per size, resulting in compliance with delivery times and improved operations efficiency, as well as more efficient usage of the resources involved. By implementing this proposal, the company enters a continuous improvement process, as this favors correct scheduling using a technological solution, opposed to that conducted empirically or informally.

The improvement of 25% was achieved for this company according to its conditions. The company is a Small-Medium Enterprise, such that it can be expected that the scheduling approach is the same for many companies of this size. A similar improvement just because of the organization of the scheduling activity can be expected for companies of the same size.

It is important to mention the relevance of having good control of data, but it is also essential to be supported by software to carry out production schedule as this is conducive to not only having a clear and reliable vision of how production orders should be executed but also to have information that leads to decision-making to process customers' orders in the best way without generating additional costs in the production of the same.

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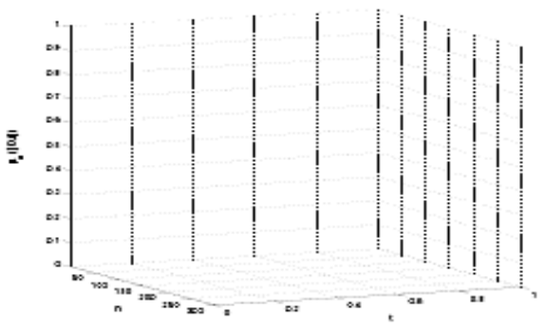

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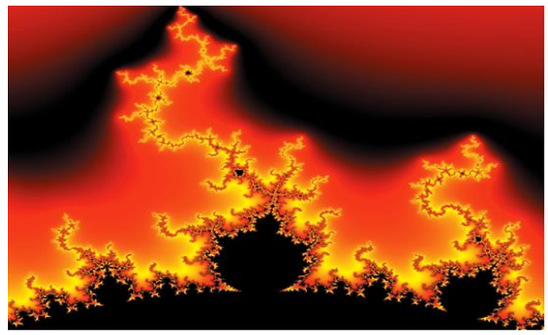

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