Motivational Impact and Promotion of Research Culture Through the Development of Deep Learning Models

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Abstract—The professional training model in Colombia is moving from a competency-based approach to learning outcomes. This path is enriched with contributions both at the level of national policies and each institution, as well as the teaching experiences and interests of the students. In this environment, this research presents the impact on the motivational level, and on the development of research skills, in undergraduate students of the electrical area generated by implementing a training scheme that involves developing research formulated and guided by the students themselves. The students come from a model based on labor competencies, and the current curricular reform proposes a new model based on learning outcomes that demands a closer follow-up of the training process of each individual. The experimental group consisted of students in a new academic space in artificial intelligence (AI), for which specific instructional material was designed so that students could build deep learning classification models for real problems while implementing a scientific development scheme that includes the generation of scientific publications. The control group maintained a traditional training scheme based on content tracking and periodic written evaluations. The results showed that although both groups achieved a high level of learning effectiveness, the experimental group demonstrated more remarkable development in their creative thinking and more significant appropriation of the academic space and the training process, with a solid self-critical position. The research concluded that the follow-up model, as well as the material developed, manages to increase the student's commitment to their training process and to generate positions on how this process is developed.

Keywords—artificial intelligence education, creative thinking, motivational impact, professional training, research culture

1 Introduction

The continuous evolution of professional environments requires the renewal of professional training processes so that they can respond correctly to the development challenges of each country. This dynamic is strongly impacted by technological developments, of which Artificial Intelligence (AI) is among the most significant impact on engineering [1]. The development of these tools has had different effects in each field, particularly regarding economic value. In electrical engineering, for example, AI corresponds to the basis of current and future engineering since it allows the design of artificial systems with the capacity to learn without being expressly programmed. This feature is essential in developing the energy sector since it enables the management of renewable energies, which is complex due to its unpredictable nature. In addition, the energy sector tends towards distributed generation, and in this scenario, the optimization of energy generation, consumption and storage requires high-performance management [2]. In this regard, programming and AI have become essential elements of students' scientific and technological cognition. Many countries, including Colombia, have adopted this trend, in which the state continuously launches training programs aimed at professionals, teachers, undergraduate students, managers and stakeholders in general from its Ministry of Information Technology and Communications (MinTIC). Nevertheless, it also stimulates the continuous updating of professional training programs of higher education institutions through its Ministry of Education (MEN) [3].

In training and education schemes, new strategies are constantly being formulated to improve students' motivation and commitment to learning since it has been demonstrated that they substantially impact meaningful learning. Some of the most successful strategies involve gamification, competitions, and those that seek to have the learner develop a self-critical view of his or her training process [4]. Many studies have reported that games have been shown, at least in the short term, to be practical tools for promoting self-directed learning, problem-solving skills, and critical thinking [5], [6]. A key element in this success is that it relies on competition, which, if linked to learning objectives, allows for a training strategy that strongly stimulates these skills. Other essential competencies for young people, particularly in developing societies, relate to the ability to propose solutions to real problems, promote applied research, and disseminate such approaches. Competition-based strategies can also be adapted to develop interactive learning, research, and socialization of results with peers [7].

AI tools are continuously developing and are still far from what could be considered a true AI. However, their current use is extensive, and to develop them further, it is necessary to know their current state. These facts justify the extensive development and current importance of Artificial Intelligence in Education (AIEd) [8]. Despite this, little can be found regarding Deep Learning (DL) in the context of education, which is relevant considering that it is the most popular branch of AI [9]. It is natural to find much more diffusion in educational contexts of technologies related to natural language processing and data mining, relegating DL and other more advanced tools. Part of the problem lies in the impossibility of applying these tools in the context of the training classroom and the lack of linkage of students' interests with the training objectives of these courses [10]. Our research seeks to attack these two problems simultaneously, identifying contexts of application of DL strategies that students can appropriate and using training strategies that encourage gaming and competition, particularly in developing a formal research project [11].

Creative thinking is crucial in developing motivation, student interest and divergent thinking. Accordingly, it is also a desirable skill for young learners when thinking about the development of society [12]. Creative thinking can be developed through strategies such as Project Based Learning (PBL) thanks to the student's immersion in the problem and the joint training process that involves the required solution [13]. Furthermore, these processes can be accompanied and favored with technological strategies that motivate Generation Z (recognized as digital natives), taking advantage of existing digital platforms [14]. The impact of these digital tools on the motivation and creativity of students in training processes has been widely documented [15]. Since the invention of the Internet and Web technologies, Generation Z has developed an approach to learning based on active participation in learning [16].

Many researchers on different implementations have adopted the strategy of learning by games and competitions, and it has been widely demonstrated that it succeeds in triggering an engaged, deep, and long-impact learning process [17], [18], [19]. However, its use requires careful design, and the learning process requires adequate and sufficient learning supports as part of the game, and its development [20]. Additional elements to consider in the design include cognitive aspects relevant to the process, meaningful real-world knowledge, challenging and learning motivators, socialization and interaction processes, and objects of analysis and reflection by the learner [21]. The process achieves its goal if it gets the student to improve the acquisition of knowledge and skills by experiencing the game's content, challenging himself to outperform his peers, and developing the proposed dynamic (solving the problem to a satisfactory state) [22], [23]. Throughout the process, the student is expected to try different methods to develop the problem according to the game's rules. In traditional training, the teacher plays the role of guide, which reduces the teacher-student interaction and, therefore, the continuous monitoring of the learning process [24], [25]. The new models are based on the interaction that guides the student in a closer way, promoting his creativity and motivation.

2 Research method

This research used as experimental subjects 55 students enrolled in an elective course of Deep Learning of the Technology cycle (training by cycles propedeudic) of the Electrical Engineering program of the Universidad Distrital Francisco José de Caldas. The Universidad Distrital is a public institution financed by the city of Bogotá (Colombia). The campus is located in one of the most depressed social areas of the city, so the students belong to the lower socio-economic strata. The students ranged in age from 18 to 22 years old, and the population was primarily male (the sample had only eight females). These 55 students were divided into two groups: the control group with traditional training comprised 33 students (four females and 29 males), and the experimental group with the new model comprised 22 students (four females and 18 males). This student population has passed at least 70% of the technological program, so they already have training in Calculus, Algebra, Physics, Electronic Circuits, Electronics and Programming.

The same teacher developed the experiment in both groups, and the curricular content in both cases was the same. In the control group, traditional classes were developed with content instruction, the development of specific workshops (eight in total throughout the academic period), and written proficiency tests (four written tests). In the experimental group, students were encouraged to develop a research project involving at least one convolutional classification model in pairs, providing them with initial ideas about the problem to be solved (a different problem for each pair). Parallel to this development, students were instructed in research strategies and project development, documentation and dissemination of results through the publication of scientific articles.

As technological support, the research used material developed under these guidelines (different and specific for each group of students) for Google's Colab platform, with support for Keras, Python, Scikit-Learn, Numpy, and Pandas. On these tools, the students developed the supervised machine learning process, both for the workshops and exercises of the control group and the research project of the experimental group. The latter group scheduled four sessions of public presentation of their progress, which would be discussed by their peers and evaluated as a performance scheme in the course. They were also motivated by the fact that the best papers would be supported for publication in an academic journal.

Throughout the experiment, and in both groups, the students' work was continuously supported concerning the objectives of each case. This support paid particular attention to constructing the theoretical concepts related to the design of convolutional classification models. Consequently, students' performance was evaluated regarding appropriate skills in the course content and its application in weakly structured problems. In addition, their creative thinking, level of personal contribution and level of solutions were also evaluated.

Given the importance of creative thinking for the development of efficient and effective solutions in engineering, the research adopted four items from the creative thinking scale, assessed according to Yağcı's self-efficacy scales [26], which includes problem-solving, cooperative learning, critical thinking, creative thinking, and algorithmic thinking. The selected items addressed the following questions:

1. Level of satisfaction when contributing new ideas for the project's development.
2. Level of satisfaction when performing repetitive tasks.
3. Level of enjoyment in designing systems to perform a task automatically.
4. Level of curiosity about the structure of the systems that perform the task and how they work.

The assessment of these questions used a 5-point Likert scale, with: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree.

The impact of the strategy was assessed as the difference between two separate tests on the two groups (control group and experimental group). The first entry test was applied to the two groups as an initial stage before starting course activities. The purpose of this test was to establish a baseline to identify the effect of the strategy. The second test, called the exit test, was applied at the end of the total course development when the students completed the course's final evaluation. Both tests consisted of 20 multiple-choice questions. The questions in these tests were designed to assess student engagement in the learning process and included eight dimensions: intention to use, perceived usefulness, perceived ease of use, perceived internal control (i.e., self-efficacy in handling the Colab/Keras/TensorFlow platform), perceived external control (i.e., conditions facilitating use), anxiety about the work platform, play and interaction with the work platform, and perceived enjoyment throughout the course. In particular, the last three dimensions (anxiety, playfulness and enjoyment) had a more significant presence in the questions, given that previous studies have shown their value in identifying student engagement behaviors. Some examples of questions in the anxiety dimension are the following:

- *I am assaulted by thoughts such as: I am going to fail. I don't know anything.*
- *During course evaluations, I feel discomfort in my stomach, such as nausea or dizziness.*
- *I get scared in classes.*

Students in the experimental group developed a convolutional classification model for different problems. Some of these problems included visual detection of the condition of electrical insulators on transmission towers, cracks in new constructions or contamination in water bodies. These problems were suggested to the students in the first week of activities, and they were encouraged to think of possible solutions before starting the theoretical studies. The students' proposals were socialized in open discussions, from which the application and its development throughout the course were narrowed down. In these discussions, the participation of the group proposing the project and their peers was evident and valuable (peer evaluation). The design of the convolutional models was guided by the material on Google Colab, taking advantage of the available virtual machine resources. The documentation of these projects was done through scientific articles, and the competition was motivated by supporting the publication of the best papers. The students had to practice the stages of problem decomposition, background research, pattern recognition, solution abstraction, solution development and results evaluation in developing the project and the article. Three development progress presentations were scheduled throughout four months, and a final presentation coincided with the exit test.

The students in the control group did not compete and maintained the general work strategies of the competency-based model designed by the Universidad Distrital. Pairs of students also organized them to develop the activities, but these activities were much more structured, creating workshops in periods of one or two weeks. They also developed different classification models, including convolutional networks, but tackled classical pattern identification problems with public databases such as MNIST (Modified National Institute of Standards and Technology database) and CIFAR-10 (Canadian Institute for Advanced Research, 10 classes). Throughout the four months, partial evaluations aimed to get students to formulate and develop solutions for these databases. The purpose of the current curriculum focuses on students learning through practical processes (learning by doing) in pursuit of deeper competency acquisition schemes. The structure of the experimental process is shown in Figure 1.

To assess the impact, we used the Paired Sample T-Test (dependent samples) to identify whether there were significant indications in the two groups' emotional impact, academic performance, and creative thinking. Analysis of covariance, or ANCOVA, was also used to compare the learning efficacy of the two groups. In this analysis, the entry test was used as the covariance, the exit test was used as the dependent variable, and the factor was the two groups. Finally, multi-variate analysis of covariance (MANCOVA) was used to test the differences between the two groups concerning the values of learning anxiety, ludification, and enjoyment.

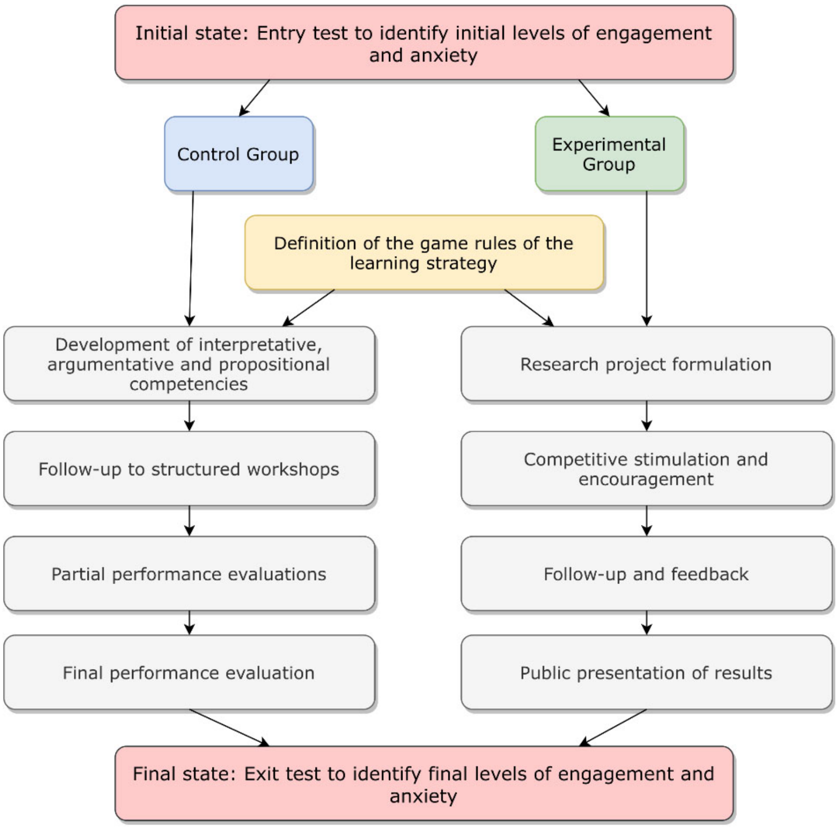

Fig. 1. Experimental process structure

3 Research results

The results were analyzed from three perspectives: concept learning outcomes, creative thinking outcomes, and motivation outcomes. The same data analysis was performed for the three cases, considering only the indicator questions for each objective. For the first case of concept learning, the Paired-Sample T Test (Table 1) results show higher values for the two groups of students. In the case of the control group, $t(32) = -3.8$ was obtained, and in the experimental group, $p(21) = -7.1$ was reached (in both cases with $p < 0.001$). In principle, these results indicate some degree of positive impact on students at the level of theoretical-practical competencies linked to the course objective independent of the learning scheme. That is, it is attributable to the content of the course and the degree of interactivity achieved in its practical use.

Table 1. Paired sample T-Test between entry and exit tests for control and experimental groups (concept learning outcomes, $p < 0.001$)

Students group	*Test*	*N*	*Mean*	*SD*	*T*
Control group	Entry test	33	41.2	14,2	-3.8
	Exit test	33	60.3	12,7	
Experimental Group	Entry test	22	40.7	13,8	-7.1
	Exit test	22	70.2	11,3	

An analysis of covariance (ANCOVA) was applied to these results to characterize the learning processes and achievements between the groups (Table 2). The adjusted mean value and standard error of the output test were 60.3 and 2.33 for the control group and 70.1 and 2.25 for the experimental group. Accordingly, $F = 7.21$ ($p = 0.0105 < 0.05$) was obtained, indicating a significant difference between the two groups. Therefore, students in the experimental group showed significantly higher learning performance than students in the control group.

Table 2. Analysis of covariance (ANCOVA): Concept learning outcomes, $p < 0.05$

Student group	*N*	*Adjusted mean*	*SE*	*F*	*p*	η^2
Control group	33	60.3	2.33			
Experimental group	22	70.1	2.25	7.21	0.0105	0.11

Regarding the results in creative thinking, the results showed that the control group did not significantly improve creative thinking (Paired-Sample T Test, Table 3). In contrast, the students in the experimental group did show a significant increase in this regard, $t(21) = -3.81$ ($p < 0.01$). Furthermore, the output test score in the experimental group was higher than the input test, while the control group showed no significant difference. Consequently, the experimental group presented a significant increase in the creative thinking processes thanks to the competition and gamification strategy of the course.

Table 3. Paired sample T-Test between entry and exit tests for control and experimental groups (creative thinking outcomes, $p < 0.01$)

Students group	*Test*	*N*	*Mean*	*SD*	*T*
Control group	Entry test	33	5.4	0.62	0.37
	Exit test	33	5.4	0.68	
Experimental Group	Entry test	22	6.2	0.57	-3.81
	Exit test	22	7.3	0.71	

Finally, regarding the results on motivation, the primary focus of the research, the results were separated into three prioritized dimensions: anxiety, playfulness, and enjoyment (Table 4). The findings showed that the behavior of the experiment group was considerably different from that of the control group. The control group showed high values in enjoyment, but the other two dimensions did not show significant differences, while the experimental group showed significant differences in all three dimensions. Relatively high anxiety was also observed in the experimental group.

Table 4. Paired sample T-Test between entry and exit tests for control and experimental groups (motivation outcomes, $p < 0.01$)

Dimension	*Students group*	*Test*	*N*	*Mean*	*SD*	*T*
Anxiety	Control group	Entry test	33	5.13	0.53	-1.11
		Exit test	33	5.26	0.59	
	Experimental Group	Entry test	22	5.23	0.38	-4.13
		Exit test	22	5.84	0.51	
Playfulness	Control group	Entry test	33	5.11	0.38	-1.15
		Exit test	33	5.23	0.46	
	Experimental Group	Entry test	22	4.89	0.33	-3.27
		Exit test	22	5.26	0.51	
Enjoyment	Control group	Entry test	33	4.68	0.41	-3.42
		Exit test	33	5.12	0.37	
	Experimental Group	Entry test	22	5.11	0.87	-3.35
		Exit test	22	5.53	0.97	

In order to solve the problem of access to higher education and greater coverage of state universities, it is customary to exceed the size of student groups in some courses. Under these conditions, the problem of close monitoring of learning outcomes by the instructor is an impossible challenge to address in the allotted time [27]. These conditions play poorly with low student interest and limited access to web-based tools. This scenario, however, can also be addressed by a careful and oriented curriculum design that allows summarizing the follow-up of students' achievements in a coherent way with the structural design of the courses and, at the same time, motivates student participation under conditions of developing a critical stance of their training process and their professional future. This study sheds light on this sense and allows observing that the student becomes more actively involved in the process without significantly increasing their anxiety levels. A change in the student's attitude towards the new work modality is evident, as well as their interaction both with their classmates and with the professor. A collateral effect not initially estimated was the increase in consultations with teachers in spaces outside the classroom, which in the population examined in the study presented almost null levels. Consequently, despite the study's limitations, it contributes to the theoretical and practical implications of applying a structure that encourages research, with curricular design oriented to learning outcomes, and in an area of engineering that is not very attractive to today's young people.

The results indicate that the content of the course and the degree of interactivity achieved in its practical use positively impacted students' theoretical-practical competencies. This suggests that interactive learning methods can be beneficial in helping students gain knowledge and skills in a particular course. The findings could be used to inform future course design and curriculum development and inform teachers on how to successfully incorporate interactive learning into their teaching. Additionally, further research could be conducted to explore the effects of interactive learning on other areas, such as student's overall academic performance, self-efficacy, and retention rates.

4 Conclusion

This research evaluated the motivational impact on a group of students concerning the change of training strategy from a competency-based approach to an approach based on learning outcomes enriched with gamification, competitiveness, and stimulation of creativity. This strategy was applied to low-income undergraduate students in a training program in electricity. The selected academic space corresponded to an AI course focused on deep networks. The strategy consisted of stimulating students to develop a research project based on motivating ideas, and the continuous monitoring of the process, so that students competed to achieve a complete, high-quality development susceptible to scientific publication. To evaluate the impact, a control group was managed in parallel, in which the students experienced the training process traditionally. In both groups, the learning process was separated into intricately connected stages, in which the learning tasks were increasingly tricky and coherent with the training process to be strengthened. The follow-up of this work required the development of specific material for each group. The results showed that both groups appropriated the course concepts correctly but that the experimental group achieved, concerning the control group, higher scores in the development of creative thinking and engagement in the learning process. Higher anxiety levels were also observed on the part of the students in the experimental group, which may be linked to competition with their peers and the novelty of the scheme. However, this anxiety in the experimental group was simultaneous to the increased learning commitment, so it had a positive impact and did not obstruct learning. This research will progress by contemplating larger samples and will seek to identify the aspects that influence student anxiety (to establish whether they are internal or external to the students). It will also consider possible cognitive and affective effects.

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