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ORIGINAL ARTICLE


Difficulty index and active learning in Education 4.0 applied to university education

Índice de dificultad y aprendizaje activo en Educación 4.0 aplicada a formación universitaria

Índice de dificuldade e aprendizagem ativa na Educação 4.0 aplicado ao ensino universitário

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KEYWORDS

active methodology,
education 4.0, difficulty
index, learning, higher
education.

ABSTRACT. The development of this research was aimed at knowing, using a methodology based on Education 4.0, if that model allows an increase in the percentage of participation of students with an adequate difficulty index in the evaluations. For this, a quantitative - qualitative mixed method was used with a case study implemented in 138 students from the University of Aconcagua (Chile) from September 2022 to July 2023. The instruments to collect the information were checklists of grades and participations (pretest and posttest), as well as a complementary survey for the students. The results indicate that the percentage of activities completed increased its mean from 45.1% to 71.3% ($p < 0.001$) with a Cohen's indicator of 0.89, highlighting a much larger effect size than typical; likewise, the difficulty index in both cases remained in the range of "adequate difficulty" varying slightly from 0.639 to 0.621 with a perception of the students that finally integrates the previous results. It is concluded that the effects of the application of Education 4.0 are positive by promoting active learning and the proper implementation of challenges for the achievement of 21st century skills.

PALABRAS CLAVE

aprendizaje, educación
4.0, educación superior,
índice de dificultad,
metodología activa.

RESUMEN. El desarrollo de esta investigación tuvo por objeto conocer, mediante la utilización de una metodología basada en Educación 4.0, si dicho modelo permite el aumento del porcentaje de participación del alumnado con un índice de dificultad adecuado en las evaluaciones. Para ello, se utilizó un método mixto cuantitativo - cualitativo con un estudio de caso implementado en 138 estudiantes de la Universidad de Aconcagua (Chile) de septiembre 2022 a julio 2023. Los instrumentos para recoger la información fueron listas de cotejo de calificaciones y participaciones (pre y postest), así como una encuesta complementaria para el alumnado. Los resultados indican que el porcentaje de actividades completadas incrementó su media de 45,1% a 71,3% ($p < 0.001$) con un indicador d de Cohen de 0,89 resaltando un tamaño del efecto mucho más grande que el típico; así mismo, el índice de dificultad en ambos casos se mantuvo en el rango de "dificultad adecuada" variando levemente de 0,639 a 0,621 con una percepción del alumnado que integra finalmente los resultados anteriores. Se concluye que los efectos de la aplicación de la Educación

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4.0 son positivos al fomentar el aprendizaje activo y la implementación adecuada de desafíos para el logro de competencias del siglo XXI.

PALAVRAS-CHAVE

aprendizagem, educação 4.0, Índice de dificuldade: Índice de dificuldade, metodologia ativa.

RESUMO. O desenvolvimento desta pesquisa teve como objetivo determinar, usando uma metodologia baseada na Educação 4.0, se esse modelo permite o aumento da porcentagem de participação dos alunos com um índice de dificuldade apropriado nas avaliações. Para isso, foi utilizado um método misto quantitativo-qualitativo em um estudo de caso com 138 estudantes da Universidade de Aconcagua (Chile) de setembro de 2022 a julho de 2023. Os instrumentos de coleta de dados incluíram listas de verificação de notas e participações (pré e pós-testes), bem como uma pesquisa complementar para os alunos. Os resultados indicam que a porcentagem de atividades concluídas aumentou de uma média de 45,1% para 71,3% ($p < 0,001$), com um indicador d de tamanho de efeito de Cohen de 0,89, destacando um tamanho de efeito muito maior do que o típico; além disso, o índice de dificuldade permaneceu dentro da faixa de "dificuldade apropriada" em ambos os casos, com uma leve variação de 0,639 para 0,621. A percepção dos alunos está alinhada com os resultados mencionados anteriormente. Em conclusão, os efeitos da implementação da Educação 4.0 são positivos ao promover a aprendizagem ativa e a implementação adequada de desafios para alcançar competências do século XXI.

1. INTRODUCTION

Throughout history, education has had the need to evolve according to technology and advances in the industry. According to authors such as Miranda et al. (2021), Education 1.0 started with the mechanization of systems and the teacher as the center; then, in Education 2.0, industrialization began along with correspondence and broadcast education, in Education 3.0, internet access, automation and the first initiatives of student-centered education emerged. Today, industry 4.0 is characterized by the unification of the physical world of production machines and the digital world (Gajek et al., 2022), so this new revolution demands an Education 4.0 that is mainly focused on the student and their adaptation to digitization.

Education 4.0 does not have a specific theoretical definition. However, it has been conceived as an educational approach that encourages the use of technologies to optimize learning and, consequently, provide innovative solutions to real and complex problems (Sifuentes Ocegueda et al., 2022). The central theme of this research is the application of the essential elements of Education 4.0 in a university education environment. According to Miranda et al. (2019), the four main components of Education 4.0 are the following:

- (i) Implementation of current Information and Communication Technologies (ICTs): The use of information and communication technologies in educational processes is focused on intensifying the educational process, increasing the interest of students in studying the topics, increasing the pace of lessons, the amount of independent work, the development of logical thinking and the culture of intellectual work positively affecting motivation in the educational process (Akimov et al., 2023).
- (ii) Incorporation of new learning methods: Learning methods must evolve along with advances in technology and changing social dynamics; they must be flexible, active, and personalized, and they must motivate students to develop valuable competencies and skills to confront real problems with an emphasis on largely autonomous work (Haderer & Ciolacu, 2022).
- (iii) Creation of innovative infrastructures to improve the learning process: Learning environments in Education 4.0 must accommodate the learning needs of students, complying with essential requirements of access to

updated equipment, software necessary for the educational process, laboratories in good working conditions and accessibility for teaching infants with special needs (Miranda et al., 2021).

(iv) Development of basic competencies in today's students: In the context of university education, desirable skills for the 21st century, transversal and disciplinary competencies, including critical thinking, creativity, innovation, cooperation, collaboration, and communication, must be trained and developed (Ramírez-Montoya et al., 2022).

For the analysis in the research, in addition to the design and implementation of a methodology based on the previous elements, a broad vision of said strategy will be taken from three variables: The percentage of activities completed by the students, the difficulty index of the evaluations and the students' perception of said methodology, describing part of their leading role in the learning process (Muduli et al., 2018).

Among the most relevant antecedents, we can mention the successful implementation of proposals based on Education 4.0, such as in the Open Laboratories of the Tecnológico de Monterrey (Miranda et al., 2019), applied in various case studies such as the Challenge Week, the Bootcamp for the creation of companies and the development of multidisciplinary research projects, having positive results in terms of the generation of new knowledge, the transfer of information between peers, the creation of innovative solutions and the active use of digital resources (Miranda et al., 2021).

An approach very similar to Education 4.0 is Problem-Based Learning (PBL), which, according to Morán-Barrios et al. (2020), can be defined as a methodology in which the starting point is a problematic situation, allowing the student to identify learning needs that facilitate a better understanding of the problem and meet the established learning objectives. This has had satisfactory results in terms of evaluation by competencies (Martín-Peña et al., 2012; Yoza & Vélez Villavicencio, 2021), practical application of ICTs (Flores & Meléndez, 2021), development of transversal competencies (González-Hernando et al., 2013), and even though its complementation with innovative strategies has been suggested (Gorbaneff & Cancino, 2009) has had better results than the case study and the traditional methodology in terms of aspects such as the assimilation of concepts (Llobet et al., 2015).

Other previous studies reveal the use of ICTs in innovative strategies such as the recording of student progress with the implementation of a panel of results, having disadvantages such as the significant added work that it entails in terms of recording and data analysis (Khalid et al., 2014), but with appreciable advantages such as offering a decision-making tool, increasing compliance with deadlines and increasing the responsibility of the people involved in the panel (Tilea & Bleotu, 2012).

Various researchers have questioned the difficulty of proposals contrary to Education 4.0, such as traditional multiple-choice tests, pointing out the inadequate complexity of the tests (Giaconi et al., 2021), the promotion of mostly rote learning (Hamp-Lyons, 2007), the need to assess higher cognitive order skills (Haataja et al., 2023), the relevance of competencies not achieved such as teamwork, critical thinking and learning to learn (Sepulveda et al., 2021), in addition to the inefficiency of these methodologies in the formation of analysis capacities, the construction of knowledge and the development of analytical responses to real problems (Richter & Medel Romero, 2020).

When carrying out an approach to the study problem, there is a need to add detailed descriptions of methodologies based on Education 4.0 (Wang et al., 2023), the small number of studies on the degree of

difficulty of evaluations oriented to transversal competencies and technological projects (Lee & Jo, 2023; Oliveira & Saraiva, 2023), in addition to the little bibliography with quantitative studies in which these strategies are evaluated (Mukul & Büyüközkan, 2023), all this driven by the increase in the competitiveness of the graduates in terms of digital demands in Industry 4.0 (AlMalki & Durugbo, 2023; Qian et al., 2023).

The objectives of the research are to design the basis of a methodology that includes the four elements of Education 4.0, apply this strategy to the students of the engineering faculty of the University of Aconcagua, determine the percentage of active participation of the students throughout the semester, calculate the difficulty indices in the applied evaluations, register the perceptions of the students about the applied methodology and integrate the previous results for the analysis of the proposed methodology.

2. METHOD

Type of study

The research had a mixed route since it represented a collection of quantitative and qualitative data to make inferences from all the information collected and understand the phenomenon studied (DeCuir-Gunby & Schutz, 2017). Likewise, an exploratory investigation was carried out since a little-known field is addressed to be clarified and delimited (Paneque, 1998). In addition to the design being typical of a case study, carrying out pre-test and post-test measurements were carried out on a specific group (Hernández Sampieri et al., 2018).

Population and sample

The population of this research is made up of students from the engineering faculty of the University of Aconcagua, Chile. The type of sampling worked has been non-probabilistic for convenience since accessible cases have been selected due to their proximity and have gone through different inclusion criteria (Otzen & Manterola, 2017). These criteria were being over 18 years of age, belonging to careers associated with electricity and industrial automation, having at least 50% class attendance, and voluntarily participating in the research process, having a final sample of 138 students.

Data collection instruments

The statistical data recording and the open questionnaire were used as research techniques, both designed "ad hoc" according to the characteristics of the study. For the quantitative data collection, there is a rubric for comparing grades and activities completed with an approach similar to that used by Suárez-Lantarón & García-Martínez (2022). To complement the research with qualitative data, an open questionnaire was used through a survey of students at the end of the semester with open questions. For the validation of the instruments to be used in the research, expert judgment was used as a method, complying with the criteria of validity and reliability to carry out the study.

As for the processing of qualitative data, the Google "Forms" application was used with the possibility of collecting long responses. Likewise, to process the quantitative data, Microsoft Excel software was used to calculate variables and the statistical parameters exposed in the results section.

3. RESULTS

In this section, the results will be divided into three parts, namely, the description of the methodological proposal with Education 4.0, the quantitative results, and the perceptions of the student body.

Methodological proposal with Education 4.0. When designing a class dynamic that meets the demands of Industry 4.0, the necessary paradigm shift must be considered, moving from a teaching-focused method to a learning-focused method (Taipe, 2020). To apply this transition, the main advantages of the following three aspects are considered:

Part I: Theoretical-practical bases

The class-to-class methodology begins with a brief theoretical explanation of the topic to be dealt with application examples (covering approximately 30% of the session time). The purpose of the proposed examples is based on the achievement of "Learning Results" with a real application of knowledge in problem-solving (Jenkins & Unwin, 2001). This style of Master Class is chosen to start the class since it is recommended as a scaffolding for learning, especially in the understanding of complex concepts and procedures (March 2006), in addition, developing each class combining active and passive strategies has demonstrated positive results in terms of the application of knowledge with reflective actions (Gagné et al., 2021).

Part II: Active learning

The application of Problem-Based Learning has shown better development of competencies than the shared study, the directed study, the expert method, and the case method (Robledo Ramón et al., 2015), which is why after finishing the first phase of the teacher-centered class proceeds to the student-centered class, proposing the resolution of problems on the exposed theme. These formative activities promote learning strategies such as self-regulation, self-assessment, affective support, and meaningful learning (Torres et al., 2021; Urquijo et al., 2014).

The proposed exercises can be basically designed in two ways: The first is to solve problems individually and in parallel, and the second is to offer students the opportunity to move on, in pairs, to solving challenges on the blackboard, a strategy recommended in groups of less than 30 students to maintain teacher-student interaction (March, 2006). In both forms, the teacher becomes a tutor and answers questions about the activity while managing the times and rhythms of the class. When the time allowed to develop the activities ends (which are designed to be completed between 20 and 30 minutes), each pair is called to explain the exercise they developed step by step. Said dynamic is based on the most profitable level of "William Glasser's Learning Pyramid," in which it is postulated that "doing and saying" is the most profitable level of the learning process, surpassing only "doing" and the passive ones "see and hear" and "listen" (Huamán Flores & Aquije Cardenas, 2023).

Part III: Semester Project

Project-based learning is one of the methodologies that require more preparation and feedback from the teacher. However, it stands out for effectively promoting the development of problem-solving skills, teamwork, and critical thinking, among others (Asunción, 2019). For this reason, at the beginning of the semester, a project of practical application of the knowledge of the matter is proposed. This is designed to be done in teams of 2-3 students every 4 weeks, a class space is dedicated to giving feedback to the teams on their progress in the Project, and it is intended to be completed in the last week of the semester. Said Project is constituted by the advantages of

the highest level in Bloom's taxonomy, the "create" level, in which the greatest development of cognitive abilities and significant learning (West, 2023).

To visualize the application of the three previous parts, Table 1 is shown, indicating the elements of Education 4.0 that are considered in a higher technical career, specifically the branch "Measuring and monitoring instruments", in which it is pursued to acquire the various learning outcomes in the field and apply the knowledge in a primary robotics contest at the end of the semester.

Table 1

Summary of methodology with Education 4.0 in a higher technical career.

University: University of Aconcagua. Chile.				
Class format: Face-to-face learning.				
Participants: 20 students of the Higher Level Technical Degree in Electricity.				
Subject: Measurement and monitoring instruments (1st year)				
Duration: 16 weeks.				
Parts	Basic components of Education 4.0			
	1. Competences	2. Learning methods	3. ICTs	4. Infrastructure
I. Theoretical-practical bases: 30% of the class explaining key concepts and examples	Critical thinking. Interpretation of circuits	Bases of challenge-based learning	Power Point slides with links to see simulations	Rooms with basic requirements
II. Active learning: Individual or small group class-to-class activities	Creativity, cooperation. Problem solving	Active and student-centered learning	Autodesk TinkerCAD software and falstad to create circuits.	Rooms for teamwork. Online Tutorials for Arduino UNO Programming
III. Semester project. Application of knowledge in groups of 2-3 with monthly feedback for robotics contest and final video summary	Communication and innovation. Implementation of a real electronic assembly	Learning based on autonomous projects	Hardware and software for a prototype of a car controlled by Arduino UNO. Microsoft Teams for recordings	Multipurpose room and logistics base organized by students. At least one computer per group for final recording.

It should be noted that as examples of semi-annual projects, there is the creation of a poster and a summary video on a technical pre-feasibility study for the manufacture of a product and even the design, programming, and assembly of a functional prototype, such as a fall arrest walker, an automatic gantry, a miniature car controlled by sensors, a drip irrigation system or a facial protection mask with monitoring of vital signs, all being proposals successfully developed during the investigation.

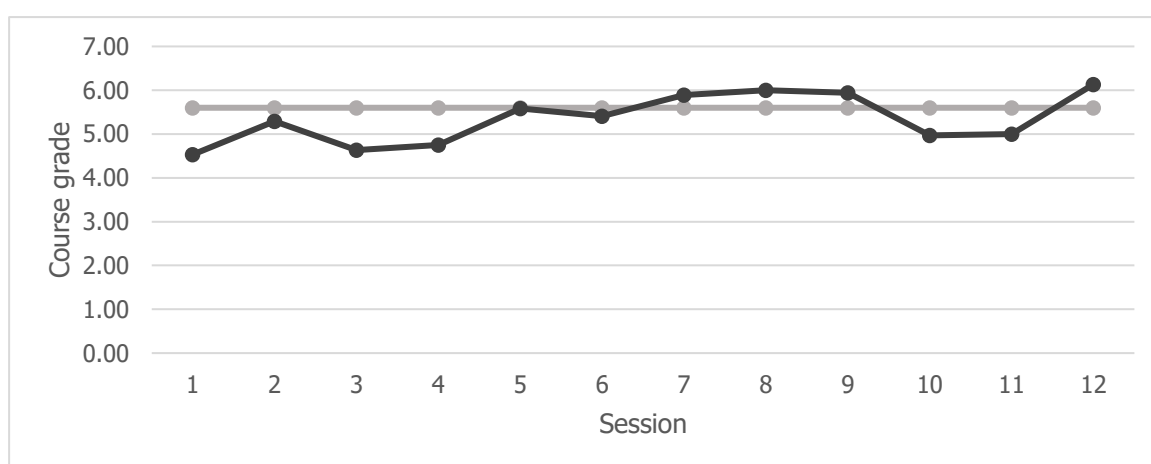
To use ICTs in the field of learning management, the conclusions reached by researchers such as Rusli & Sutopo (2016) were used, indicating that visualization on a board can increase motivation in a work team and the ability to complete a task at a scheduled time. Therefore, the grades of the students in the progress of the Project, as well as in the class-to-class activities, were reflected in a shared graph from the beginning of the semester. This graph is shared in real-time thanks to an Excel document configured to be "read-only" by the students.



Said graph showed the "Expected average," which represents the objective average grade of the entire course in each class (5.6 points), being 80% of the maximum grade (7.0 points), an agreed quality criterion. In advance with the students, and that is consistent with the needs of the students (Elrehail et al., 2018). Likewise, the "Real Average" is shown with the average grades obtained class by class by all the students attending. Said difference is made with Excel formulas such as =PROMEDIO.SI(C21:C46,">1"), where C21:C46 is any matrix that includes the grades of the students on a specific day and ">1" a comparison with the minimum grade, in this case 1, which would seek to rule out absent students from the visualized average. With this formula, each class would have an actual average (dark line), which could be clearly compared with the expected average (light line), as shown in Figure 1.

Figure 1

ICTs applied to the scoreboard in real time



Note: The figure represents the chart in Excel shared with students. Source: Self-made.

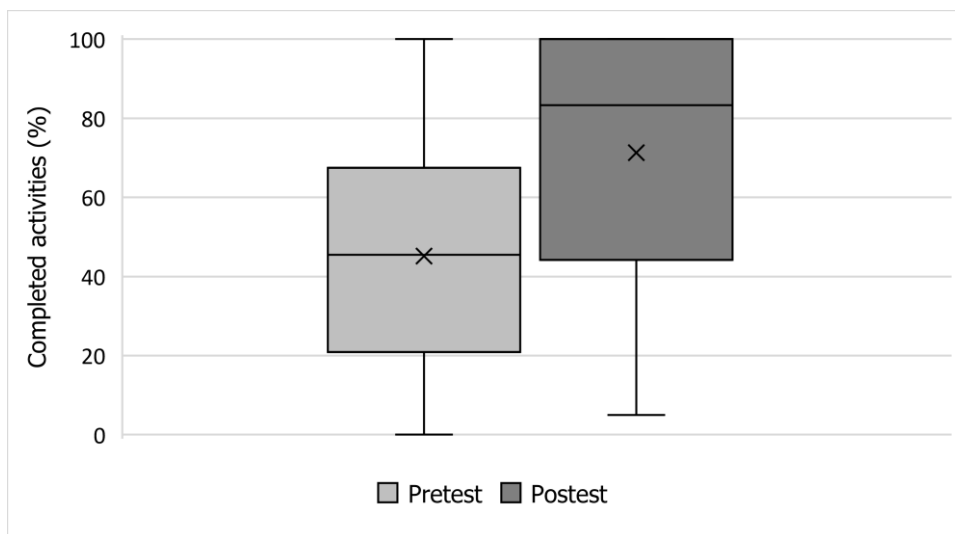
Similar strategies have been successfully tested in Industry 4.0 and Education 4.0, highlighting that, since you know if you are winning or losing, there is a commitment on an emotional level, you also work harder to not disappoint your colleagues. Also, it is a tool that allows team and leaders to appreciate their responsibility for the team's success (Covey, 2013; Khalid et al., 2014; Rusli & Sutopo, 2016).

Quantitative results. After applying the previous methodologies according to the needs of each course, quantitative and qualitative results were obtained. To visualize the results obtained, the figures collated in the 2nd semester of 20 are compared. 22 (pre-test) applying only the basic principles of Problem-Based Learning, and the 1st semester of 2023 (post-test) with an emphasis on the four components of Education 4.0 applied during the investigation.

The first quantitative variable is the percentage of activities completed by the student body, obtained simply as the relationship between the activities completed and the total number of activities proposed in the subject studied by each student. Gathering the results obtained in the students, there are dispersions of points that can be summarized in the diagrams of Figure 2.

Figure 2

Boxplot of the percentage of activities completed pretest and posttest



Note. The figure compares the percentage of activities completed with only PBL as the implemented methodology (pretest) and after implementing the methodology based on Education 4.0 (posttest). Source: Self-made.

Para el análisis de los datos fue utilizado el indicador *d* de Cohen, el cual mide el tamaño del efecto en una intervención y se calcula restando las medias de los dos grupos y dividiendo el resultado entre la desviación estándar promedio (Cohen, 2013). Si el resultado se aproxima a 0,0 se tiene ausencia de efecto, con 0,3 se tiene una fuerza del efecto típica, cerca de 0,5 se tiene un efecto más grande que el típico y más de 0,7 se tiene un efecto mucho más grande que el típico (Castillo, 2009). Los resultados obtenidos se resumen en la tabla 3.

Table 3

Summary of percentage of activities completed during the pretest (with only Problem-Based Learning) and posttest (ABP and Education 4.0 applied)

	Mean	Standard deviation	d-Cohen	p
Pretest	45,122	27,815		
Posttest	71,304	30,402	0,899	0,000

In each evaluation carried out during the investigation, a quantitative parameter was calculated and monitored, which helps the progressive design of the evaluations. Said indicator was the difficulty index (IDT), which is obtained by dividing the average of the scores obtained by the participants in the test by the maximum score that the test is worth (Cárdenas Ayala, 2013). From there, values between 0 and 1 can be obtained, which must be interpreted as follows: Between 0.00 and 0.10 the test is classified as very difficult, between 0.11 and 0.30 as difficult, between 0.31 to 0.50 as relatively difficult, between 0.51 and 0.65 as having adequate difficulty, between 0.66 and 0.80 as relatively easy, and from 0.81 to 1.00 as very easy (Cárdenas Ayala, 2022). The resulting difficulty indices were summarized in Table 4.

Table 4

Summary of difficulty indices (IDT) obtained in the pretest (ABP applied) and in the posttest (ABP and Education 4.0 applied)

	IDT EV1	IDT EV2	IDT EV3	Average IDT	Average difficulty
Pretest	0,639	0,649	0,629	0,639	Adequate
Posttest	0,627	0,626	0,611	0,621	Adequate

Student perceptions. At the end of the semester in which the study methodology was implemented, an interview was applied to have an observation of the students on aspects of the course as a complement to the investigation and a starting point for continuous improvement. This instrument was qualitative and consisted of two open questions developed in Table 5.

Table 5

Perceptions provided by students about the experience with Education 4.0

Section	Frequent Answers
1. Positive aspects of the methodology used in the semester	<ul style="list-style-type: none"> • The semester project was entertaining and challenging, facing works like the thesis prepares for the future. • Learning by doing is highlighted and that software is helpful in the workplace. • The daily exercises make for continuous effort, they strengthened ties with classmates. • In case of having low grades there is flexibility to raise them and maintain them, so that what is complicated becomes easy to understand. • The fear of participating in classes is being overcome. • The results board with the notes keeps you informed to improve and shows transparency in the evaluation
2. Aspects for improvement of the methodology used in the semester	<ul style="list-style-type: none"> • With the public results board, differences of opinion can be generated due to classmates' notes. • More activities are suggested in which students explain the contents in their own words. • There should be an even more equipped laboratory. • For work and family reasons, activities are lost from class to class, and it is not easy to catch up. • Sessions longer than 80min should be held for more consultation and feedback on the semester project.

4. DISCUSSION

The results obtained in the research show a basic explanation of a methodology based on Education 4.0 that brings together the main advantages of project-based learning, problem-based learning, and theoretical foundations while taking into consideration the four components of Education 4.0, being the application of ICTs, active learning, skills development, and adequate infrastructure (Akimov et al., 2023; Haderer & Ciolacu, 2022;

Miranda et al., 2021; Ramírez-Montoya et al., 2022), also demonstrating that the previous aspects could be applied in practice with satisfactory results such as those indicated below.

First, the percentage of activities completed by students rose from an average of 45.1% (pre-test only with Problem-Based Learning) to 71.3% (post-test with Education 4.0) with a notable effect of the intervention, since the coefficient Cohen's d was 0.899, indicating a much more significant effect than typical (Castillo, 2009), this with a p -value of less than 0.001, highlighting the statistical significance of the figures obtained (Choi & Kim, 2023).

Likewise, the difficulty indices in the tests carried out remained with similar figures, resulting in 0.639 in the pre-test and changing to 0.621 in the post-test, both values are between 0.51 and 0.65, placing themselves in the range described as "adequate difficulty" (Cárdenas Ayala, 2022). This result presents a new contribution to the study of innovative methodologies since it shows that the transition to Education 4.0 can represent a balanced challenge, neither frustratingly difficult nor unnecessarily easy.

As a complement, qualitative results were obtained in which the students gave their perceptions about the methodology used. When summarizing the meaning of the positive points observed by the students, it highlights the appreciation of autonomous learning spaces, continuous activity as an important value in classes, and the usefulness of projects for future preparation and learning with the help of Useful ICTs for the labor field in Industry 4.0. In these observations, the four principles to be taken into account in adult education are highlighted, being (i) Autonomy, (ii) Interactivity, (iii) Adherence to the priority task or mission and (iv) Immediate application (Ramírez Vanegas, 2022).

Regarding the aspects to be improved that the students indicated, some discrepancies are pointed out in the appreciation of the grades given to classmates, the intermittent difficulty in adapting to the active rhythm of the classes, and the need for more time to cover the great number of learning outcomes with review classes. These observations are consistent with the three challenges expected in the application of active methodologies such as this, being complete continuous feedback, flexibility in the face of the different needs of the students, and efficiency in the use of time and resources (Gueye & Exposito, 2020). In general terms, it is observed that the perceptions agree with the quantitative results since the active learning of the students is notorious, and the balanced difficulty of the challenges presented being balanced between relatively easy and relatively difficult.

The limitations encountered during the development of the research can be summarized as the lack of up-to-date equipment in the laboratories and the difficulties in managing time in the sessions since the demands of such an innovative proposal require a profound restructuring of the infrastructure, both in the physical part as well as in the design of subject programs, since these must promote not only the massive impartation of knowledge but also provide spaces for practical applications, continuous feedback and review of contents. As a possible bias to consider in the results obtained, it should be considered that the exposed strategies have been applied in careers associated with science and technology, making it unfeasible to generalize all the findings when innovating in humanities or health sciences since there must be an adequate adaptation in such cases.

In addition, based on the previous analysis, new lines of research are proposed that expand Education 4.0 applied in environments outside of careers such as engineering (focusing on the real application of knowledge and the approximation to the technological demands required of professionals in Industry 4.0), deeper qualitative routes are suggested that include the perceptions of teachers and new topics in which students are more fully

prepared for the high demands of the workforce in terms of key competencies of the 21st century such as adaptability, technological literacy, teamwork, critical thinking and creativity.

5. CONCLUSIONS

To conclude, it can be affirmed that the foundations of Education 4.0 are successfully implemented in the field of university education in careers related to electricity and industrial automation, considering the advantages of Project-based learning, class-to-class exercises, and the basic support of theoretical classes with application examples.

The level of student participation when a methodology such as the above is applied is notably higher than when only problem-based learning is used, since the effectiveness of the ICT tools used, the comprehensive development of skills and the management of active learning (inside and outside the classroom) positively complements the dynamism of the classes.

The difficulty index in the evaluations based on Education 4.0 is adequate, neither inadequately easy nor inadequately difficult. Likewise, this strategy can be applied starting from the primary application of an active methodology without negatively altering the weight of the challenge in the summative aspects of the classes.

The perception of the student body regarding innovative methodologies is mostly positive, highlighting critical aspects in adult education, such as the orientation of the classes towards the development of useful skills in the labor field, the creation of conditions for the autonomous expression of capacities, the activity in the student that empowers him as the protagonist of his learning and the relationship with his primary needs.

Educational institutions have the responsibility of adapting to the demands of the growing industry 4.0, with the objective of developing a student capable of assuming the new challenges of the real world. For this, it is key to create basic conditions in the infrastructure so that classes can be taught with new active learning methods, technologies that optimize this process are used and the development of key competencies in the 21st century is targeted, creating comprehensive and valuable professionals for the development of society.

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Aspectos éticos / legales; Ethics / legals:

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REFERENCES

- Akimov, N., Kurmanov, N., Uskelenova, A., Aidargaliyeva, N., Mukhiyayeva, D., Rakhimova, S., Raimbekov, B., & Utegenova, Z. (2023). Components of education 4.0 in open innovation competence frameworks: Systematic review. *Journal of Open Innovation: Technology, Market, and Complexity*, 9(2), 100037. <https://doi.org/https://doi.org/10.1016/j.joitmc.2023.100037>
- AlMalki, H. A., & Durugbo, C. M. (2023). Evaluating critical institutional factors of Industry 4.0 for education reform. *Technological Forecasting and Social Change*, 188, 122327. <https://doi.org/https://doi.org/10.1016/j.techfore.2023.122327>
- Asunción, S. (2019). Metodologías Activas: Herramientas para el empoderamiento docente. *Revista Docentes 2.0*, 7(1), 65–80.
- Cárdenas Ayala, A. (2013). Índice de dificultad y asimetría de los ítems en las pruebas pedagógicas. *Horizonte de La Ciencia*, 3(5), 65. <https://doi.org/10.26490/uncp.horizonteciencia.2013.5.77>
- Cárdenas Ayala, A. (2022). Análisis estadístico del índice de dificultad de los ítems politómicos en las pruebas pedagógicas. *Prospectiva Universitaria*, 8(2). <https://doi.org/10.26490/uncp.prospectivauniversitaria.2011.8.1280>
- Castillo, I. I. (2009). Evaluación de resultados clínicos (II): Las medidas de la significación clínica o los tamaños del efecto. *Norte de Salud Mental*, 8(34), 94–110.
- Choi, W., & Kim, I. (2023). Averaging p-values under exchangeability. *Statistics & Probability Letters*, 194, 109748. <https://doi.org/https://doi.org/10.1016/j.spl.2022.109748>
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic press.
- Covey, S. (2013). *Las 4 disciplinas de la ejecución: cómo alcanzar metas crucialmente importantes*. Conecta.
- DeCuir-Gunby, J. T., & Schutz, P. A. (2017). Mixed methods designs: Frameworks for organizing your research methods. *Developing a Mixed Methods Proposal: A Practical Guide for Beginning Researchers*, 83–106.
- Elrehail, H., Emeagwali, O. L., Alsaad, A., & Alzghoul, A. (2018). The impact of Transformational and Authentic leadership on innovation in higher education: The contingent role of knowledge sharing. *Telematics and Informatics*, 35(1), 55–67. <https://doi.org/https://doi.org/10.1016/j.tele.2017.09.018>
- Flores, L., & Meléndez, C. (2021). Análisis comparativo del b-learning y e-learning en competencias TIC para la docencia en educación superior. *Revista Innova Educación*, 3(4). <https://doi.org/10.35622/j.rie.2021.04.013>
- Gagné, M., Hamel, C., Lauzier, S., Penney, S.-E., Bourbeau, J., Moisan, J., & Boulet, L.-P. (2021). Comparative educational outcomes of an active versus passive learning continuing professional development activity on self-management support for respiratory educators: A non-randomized controlled mixed-methods study. *Nurse Education in Practice*, 57, 103256. <https://doi.org/https://doi.org/10.1016/j.nepr.2021.103256>



- Gajek, A., Fabiano, B., Laurent, A., & Jensen, N. (2022). Process safety education of future employee 4.0 in Industry 4.0. *Journal of Loss Prevention in the Process Industries*, 75, 104691. <https://doi.org/https://doi.org/10.1016/j.jlp.2021.104691>
- Giaconi, E., Bazán, M. E., Castillo, M., Hurtado, A., Rojas, H., Giaconi, V., & Guiraldes, E. (2021). Análisis de pruebas de opción múltiple en carreras de la salud de la Universidad Mayor. *Investigación En Educación Médica*, 40, 61–69. <https://doi.org/10.22201/fm.20075057e.2021.40.21365>
- González-Hernando, C., Martín-Villamor, P., Carbonero-Martín, M. Á., & Lara-Ortega, F. (2013). Evaluación por competencias de los estudiantes de Enfermería a través de Aprendizaje Basado en Problemas. *Enfermería Universitaria*, 10(4), 120–124. [https://doi.org/https://doi.org/10.1016/S1665-7063\(13\)72640-X](https://doi.org/https://doi.org/10.1016/S1665-7063(13)72640-X)
- Gorbaneff, Y., & Cancino, A. (2009). Mapa Conceptual Para El Aprendizaje Basado En Problemas. *Estudios Gerenciales*, 25(110), 111–124. [https://doi.org/https://doi.org/10.1016/S0123-5923\(09\)70064-6](https://doi.org/https://doi.org/10.1016/S0123-5923(09)70064-6)
- Gueye, M. L., & Exposito, E. (2020). University 4.0: The industry 4.0 paradigm applied to education. *IX Congreso Nacional de Tecnologías En La Educación*.
- Haataja, E. S. H., Tolvanen, A., Vilppu, H., Kallio, M., Peltonen, J., & Metsäpelto, R.-L. (2023). Measuring higher-order cognitive skills with multiple choice questions –potentials and pitfalls of Finnish teacher education entrance. *Teaching and Teacher Education*, 122, 103943. <https://doi.org/https://doi.org/10.1016/j.tate.2022.103943>
- Haderer, B., & Ciolacu, M. (2022). Education 4.0: Artificial Intelligence Assisted Task- and Time Planning System. *Procedia Computer Science*, 200, 1328–1337. <https://doi.org/https://doi.org/10.1016/j.procs.2022.01.334>
- Hamp-Lyons, L. (2007). The impact of testing practices on teaching: Ideologies and alternatives. *International Handbook of English Language Teaching, September 2014*.
- Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, P. (2018). *Metodología de la investigación* (Vol. 4). McGraw-Hill Interamericana México.
- Huamán Flores, E. J., & Aquije Cardenas, G. A. (2023). *Guía técnico-pedagógica para la planificación curricular por competencias*. Editorial Universidad Autónoma de Ica. <http://repositorio.autonomaedu.pe/handle/autonomaedu/2239>
- Jenkins, A., & Unwin, D. (2001). *How to write learning outcomes*. University of Baltimore. <https://cutt.ly/ewvfi1D>
- Khalid, S., Knouzi, N., Tanane, O., & Talbi, M. (2014). Balanced Scoreboard, the Performance Tool in Higher Education: Establishment of Performance Indicators. *Procedia - Social and Behavioral Sciences*, 116, 4552–4558. <https://doi.org/https://doi.org/10.1016/j.sbspro.2014.01.984>
- Lee, N., & Jo, M. (2023). Exploring problem-based learning curricula in the metaverse: The hospitality students' perspective. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 32, 100427. <https://doi.org/https://doi.org/10.1016/j.jhlste.2023.100427>

- Llobet, J. R., Álvarez, M. R., & Velez, O. C. (2015). Aprendizaje Basado en Problemas, Estudio de Casos y Metodología Tradicional: Una Experiencia Concreta en el Grado en Enfermería. *Procedia - Social and Behavioral Sciences*, 196, 163–170. <https://doi.org/https://doi.org/10.1016/j.sbspro.2015.07.029>
- March, A. F. (2006). Metodologías activas para la formación de competencias. *Educatio Siglo XXI*, 24, 35–56.
- Martín-Peña, M. L., Díaz-Garrido, E., & del Barrio Izquierdo, L. (2012). Metodología docente y evaluación por competencias: una experiencia en la materia Dirección de Producción. *Investigaciones Europeas de Dirección y Economía de La Empresa*, 18(3), 237–247. <https://doi.org/https://doi.org/10.1016/j.iedee.2012.05.003>
- Miranda, J., Lopez, C. S., Navarro, S., Bustamante, M. R., Molina, J. M., & Molina, A. (2019). Open Innovation Laboratories as Enabling Resources to Reach the Vision of Education 4.0. *Proceedings - 2019 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2019*. <https://doi.org/10.1109/ICE.2019.8792595>
- Miranda, J., Navarrete, C., Noguez, J., Molina-Espinosa, J. M., Ramírez-Montoya, M. S., Navarro-Tuch, S. A., Bustamante-Bello, M. R., Rosas-Fernández, J. B., & Molina, A. (2021). The core components of education 4.0 in higher education: Three case studies in engineering education. *Computers and Electrical Engineering*, 93. <https://doi.org/10.1016/j.compeleceng.2021.107278>
- Morán-Barrios, J., Ruiz de Gauna, P., Ruiz Lázaro, P. M., & Calvo, R. (2020). Metodologías complementarias de aprendizaje para la adquisición de competencias en la formación de especialistas y actividades profesionales confiables. *Educación Médica*, 21(5), 328–337. <https://doi.org/https://doi.org/10.1016/j.edumed.2020.02.001>
- Muduli, A., Kaura, V., & Quazi, A. (2018). Pedagogy or andragogy? Views of Indian postgraduate business students. *IIMB Management Review*, 30(2), 168–178. <https://doi.org/https://doi.org/10.1016/j.iimb.2018.01.008>
- Mukul, E., & Büyükoçkan, G. (2023). Digital transformation in education: A systematic review of education 4.0. *Technological Forecasting and Social Change*, 194, 122664. <https://doi.org/10.1016/J.TECHFORE.2023.122664>
- Oliveira, S. R. M., & Saraiva, M. A. (2023). Leader skills interpreted in the lens of education 4.0. *Procedia Computer Science*, 217, 1296–1304. <https://doi.org/https://doi.org/10.1016/j.procs.2022.12.327>
- Otzen, T., & Manterola, C. (2017). Técnicas de Muestreo sobre una Población a Estudio. *International Journal of Morphology*, 35(1), 227–232. <https://doi.org/10.4067/S0717-95022017000100037>
- Paneque, R. J. (1998). Metodología de la Investigación. *Elementos Básicos Para La Investigación Clínica*. 1ra Ed. Havana: ECIMED.
- Qian, Y., Vaddiraju, S., & Khan, F. (2023). Safety education 4.0 – A critical review and a response to the process industry 4.0 need in chemical engineering curriculum. *Safety Science*, 161, 106069. <https://doi.org/https://doi.org/10.1016/j.ssci.2023.106069>
- Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex Thinking in the Framework of Education 4.0 and Open Innovation—A Systematic Literature Review. *Journal of Open*

- Innovation: Technology, Market, and Complexity*, 8(1), 4.
<https://doi.org/https://doi.org/10.3390/joitmc8010004>
- Ramírez Vanegas, D. N. (2022). La aplicación de la andragogía en la educación no formal. *Revista Docencia Universitaria*, 3(1). <https://doi.org/10.46954/revistadusac.v3i1.46>
- Richter, K. G., & Medel Romero, R. A. (2020). Item analysis of a multiple-choice test of incoming EFL students at a public university in Guanajuato State. *Estudios de Lingüística Aplicada*, 71. <https://doi.org/10.22201/enallt.01852647p.2020.71.900>
- Robledo Ramón, P., Fidalgo Redondo, R., Arias Gundín, O., & Álvarez Fernández, L. (2015). Percepción de los estudiantes sobre el desarrollo de competencias a través de diferentes metodologías activas. *Revista de Investigación Educativa*, 33(2 SE-Artículos), 369–383. <https://doi.org/10.6018/rie.33.2.201381>
- Rusli, M., & Sutopo, H. (2016). Multimedia based scoreboard development of four disciplines of execution for journal publication. *2016 8th International Conference on Knowledge and Smart Technology (KST)*, 120–124.
- Sepulveda, P., Cabezas, M., García, J., & Fonseca-Salamanca, F. (2021). Aprendizaje basado en problemas: percepción del proceso enseñanza aprendizaje de las ciencias preclínicas por estudiantes de Kinesiología. *Educación Médica*, 22(2), 60–66. <https://doi.org/https://doi.org/10.1016/j.edumed.2019.01.004>
- Sifuentes Ocegueda, A. T., Sifuentes Ocegueda, E. L., & Rivera Barajas, J. M. (2022). Educación 4.0, modalidad educativa y desarrollo regional integral. *IE Revista de Investigación Educativa de La REDIECH*, 13. https://doi.org/10.33010/ie_rie_rediech.v13i0.1452
- Suárez-Lantarón, B., & García-Martínez, Á. (2022). Grupos interactivos y su influencia en el rendimiento académico en el aula de primaria: estudio de caso. *Revista Innova Educación*, 4(2). <https://doi.org/10.35622/j.rie.2022.02.005>
- Taipe, M. D. (2020). Metodologías activas en el proceso enseñanza-aprendizaje. (Revisión). *Roca: Revista Científico-Educaciones de La Provincia de Granma*, 16(1), 463–472.
- Tilea, D. M., & Bleotu, V. (2012). Implementation of a Scoreboard in Schools Based on Performance Indicators. *Procedia - Social and Behavioral Sciences*, 46, 2472–2476. <https://doi.org/https://doi.org/10.1016/j.sbspro.2012.05.505>
- Torres, J., Chávez, H., & Cadenillas, V. (2021). Evaluación formativa: una mirada desde sus diversas estrategias en educación básica regular. *Revista Innova Educación*, 3(2). <https://doi.org/10.35622/j.rie.2021.02.007>
- Urquijo, A. P. L., del Valle, E. R., & Salvo, C. A. (2014). Estrategias de aprendizaje en educación superior en un modelo curricular por competencias. *Revista de La Educación Superior*, 43(172), 123–144. <https://doi.org/https://doi.org/10.1016/j.resu.2015.03.012>
- Wang, K., Li, B., Tian, T., Zakuan, N., & Rani, P. (2023). Evaluate the drivers for digital transformation in higher education institutions in the era of industry 4.0 based on decision-making method. *Journal of Innovation & Knowledge*, 8(3), 100364. <https://doi.org/https://doi.org/10.1016/j.jik.2023.100364>

- West, J. (2023). Utilizing Bloom's taxonomy and authentic learning principles to promote preservice teachers' pedagogical content knowledge. *Social Sciences & Humanities Open*, 8(1), 100620. <https://doi.org/https://doi.org/10.1016/j.ssaho.2023.100620>
- Yoza, A., & Vélez Villavicencio, C. E. (2021). Aporte de las tecnologías del aprendizaje y conocimiento en las competencias digitales de los estudiantes de educación básica superior. *Revista Innova Educación*, 3(4). <https://doi.org/10.35622/j.rie.2021.04.004>

