

Evaluation of the Effects on Achievement of a Technology-Enriched Teaching Method, Once Controlling for the Effect of Ability and Prior Knowledge in University Students

Evaluación de los efectos sobre el rendimiento de un método de enseñanza enriquecido con tecnología, una vez controlado el efecto de la capacidad y los conocimientos previos en estudiantes universitarios

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ABSTRACT

This study evaluates the effects of a technology-enriched instructional design on academic achievement in higher education, statistically controlling for students' prior ability and knowledge. Grounded in constructivist and situated learning theories, the intervention integrates the ADDIE instructional design model with the SAMR framework for educational technology integration. A quasi-experimental design with non-equivalent control groups and pretest–posttest measures was implemented with 415 undergraduate students enrolled in the Pedagogy of Language and Literature program at the Central University of Ecuador between 2020 and 2023. Of these, 218 students participated in the experimental condition receiving a technology-supported instructional design implemented through Moodle and videoconferencing tools, while 197 students followed a traditional teaching approach. Data were analyzed using repeated measures ANOVA, incorporating university entrance examination scores as a covariate to control for prior ability and knowledge. Results indicate a statistically significant, though moderate, positive effect of the technology-enriched teaching method on global academic achievement, independent of initial differences in ability and prior knowledge. These findings contribute empirical evidence to the literature on

instructional design effectiveness, educational technology integration, and academic achievement in teacher education programs.

Keywords: Technology-Enriched Instructional Design; Academic Achievement; Educational Technology Integration; Quasi-Experimental Design; Higher Education

RESUMEN

Este estudio evalúa los efectos de un diseño instruccional enriquecido con tecnología sobre el rendimiento académico en educación superior, controlando estadísticamente la capacidad y los conocimientos previos del estudiantado. Fundamentado en los principios del constructivismo y el aprendizaje situado, el modelo integra el enfoque ADDIE de diseño instruccional con el marco SAMR para la integración educativa de tecnologías. Se aplicó un diseño cuasiexperimental con grupo de control no equivalente y medidas pretest–postest en una muestra de 415 estudiantes de la carrera de Pedagogía de la Lengua y la Literatura de la Universidad Central del Ecuador durante el período 2020–2023. De ellos, 218 participaron en la condición experimental con un diseño instruccional soportado por tecnología implementado mediante Moodle y herramientas de videoconferencia, mientras que 197 siguieron un enfoque de enseñanza tradicional. Los datos se analizaron mediante un ANOVA de medidas repetidas, incorporando como covariable la puntuación del examen de acceso a la universidad para controlar el efecto de la capacidad y los conocimientos previos. Los resultados evidencian un efecto positivo y estadísticamente significativo, aunque moderado, del método de enseñanza enriquecido con tecnología sobre el rendimiento académico global, independiente de las diferencias iniciales en habilidad y conocimiento previo. Estos hallazgos aportan evidencia empírica a la literatura sobre eficacia del diseño instruccional, integración de tecnología educativa y rendimiento académico en programas de formación docente.

Palabras Clave: Diseño Instruccional Enriquecido Con Tecnología; Rendimiento Académico; Integración De Tecnología Educativa; Diseño Cuasiexperimental; Educación Superior

INTRODUCTION

The effective integration of technology into the teaching and learning process has become an educational goal today, as it is considered to support more efficient, effective, and engaging learning and teaching. The media and activities that are planned in the educational process must help achieve the educational objectives set within the rigorous planning of an instructional design model. Technology has eliminated the distance between the actors in the educational process (Ornstein and Hunkins, 2017). However, although technology has been taking a predominant place in the educational process (Dusek, 2006; Spector, 2014) it is necessary to deepen the analysis of the effects of virtual

teaching as an instructional resource and the conditions under which this teaching becomes more effective (Reigeluth, 2016).

Furthermore, reviews of the scientific literature on the effects of using new technologies in teaching on academic achievement, carried out around the PISA program in non-university education stages, highlight the limitations of technology, by itself, for improving students' academic achievement, and the need to integrate this technology into an instructional design that enables the creation of global learning environments that favor knowledge acquisition and achievement (Hattie, 2009; 2023; Reitmann and Aditomo, 2013). Teaching is a process that requires a holistic and integrative critical analysis of both the theoretical frameworks that support it and the context in which it develops, and this field is increasingly influenced by technology (Gallego and Raposo, 2016).

Current instructional design models integrate theoretical principles of constructivism and situated learning, as well as technological tools that enable effective learning environments (Jonassen, 2000; Ornstein and Hunkins, 2017; Reigeluth et al, 2017). Instructional design models must be sensitive to different contexts and also respond to complex teaching and learning issues (Branch and Dousay, 2022). According to Reiser and Dempsey (2018), instructional design must have seven characteristics: 1) It is student-centered, 2) It is goal-oriented; 3) It is a creative process; 4) It focuses on meaningful performance; 5) It assumes that the results are measurable, reliable, and valid; 6) It is an empirical, iterative, and self-correcting process; 7) It usually involves a team effort.

For his part, Merrill (2013) proposes five principles of instruction: 1) Students must be engaged in solving meaningful problems, 2) Existing student knowledge relevant to the task must be activated, 3) New knowledge and skills must be demonstrated in an appropriate context, 4) Students must have ample opportunities to apply new knowledge and skills with feedback, 5) Students must be encouraged to make knowledge and skills part of their daily lives as much as possible.

One of the multiple and most widespread instructional design models is the ADDIE model, which corresponds to the acronym for Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The teacher faces the challenge of educationally integrating technologies into teaching, based on learning theories and principles, to contribute to enriching teaching and learning environments in a way that leads to an improvement in the learner's skills (Spector, 2016), as well as satisfying the requirements of a new problem or situation.

For Spector (2016), the integration of technologies in education is based on the following principles: 1) The integration of technology in education should improve learning, achievement, and/or instruction. 2) Stakeholders must be informed, and key users must be adequately trained on new technologies. 3) Training teachers and IT staff on how to see effective pedagogical use of the new technology is essential. 4) Training users on

the new technology is critical. 5) Adequate support for a new technology should be an important part of the deployment. 6) A systematic representation of the roles and use of new technologies should be developed prior to implementation. 7) The costs of technology should not outweigh the benefits. 8) Technology should not be expected to change learning and instruction quickly and magically.

For their part, Reigeluth, Myers, and Lee (2017) state that “to support student-centered instruction, technology should be used wherever appropriate to fulfill the following functions: record keeping for learning, planning for learning, instruction for learning, assessment by and for learning” (p. 24-25). An integration model helps the actors in the educational process incorporate technology into teaching, learning, and/or assessment activities (Castillo and Cabrerizo, 2006).

Multiple Integration Models exist such as TIM, Triple-E, Tpack, SAMR, the latter being the one used in this research. The Substitution, Augmentation, Modification, Redefinition (SAMR) model offers a method for seeing how computer technology can help in teaching and learning (Chasi, Cazar, and Ramírez, 2017). The four levels of technology integration are: 1) Substitution: Technology acts as a direct tool substitute, with no functional change; 2) Augmentation: Technology acts as a direct tool substitute, with functional improvement; 3) Modification: Technology allows for significant task design; 4) Redefinition: Technology allows for the creation of new tasks, previously no used. The application of the SAMR model is reflected in the design of the activities incorporated into the teaching-learning process, ensuring that technology is not merely a replacement but is used to enhance, transform, and create new learning experiences. This model also relates to and is supported by Bloom’s taxonomy. In this work, the ADDIE instructional design model, enriched by technology and complemented by the SAMR integration model, is implemented.

On the other hand, although university academic achievement is a multicausal theoretical construct, the product of various social, institutional, and personal determinants (Díaz-García et al., 2023; Garvanzo, 2007; Verdugo-Guamán et al., 2023), synthesis studies on the factors that influence academic achievement (Castejón, 2014; Hattie, 2009; 2023; Hattie and Anderman, 2013) show that teaching methods, especially those that present some characteristics such as clear and structured teacher explanation, practice, and frequent feedback, have a significant influence on academic achievement. Academic achievement is associated with grades or scores (Medina et al., 2018).

One of the factors that most influences student achievement is the personal variables of abilities and prior knowledge (Castejón, 2014; Hattie, 2009; 2023), so the evaluation of the effect of any educational method such as the technology-enriched instructional design proposed in this study, must methodologically consider the possible effect of these factors on achievement, so that if an effect of the teaching method on achievement occurs, it is independent of the individual variables of abilities and prior knowledge.

Based on this context, the objective of this work is to evaluate the effects of the application of a technology-supported instructional design, based on theoretical principles aimed at creating effective learning environments, on the academic achievement of university students, once the effect of general ability and prior knowledge, evaluated by the Ecuadorian university entrance examination, is statistically controlled.

METHOD

Participants

The participants were 415 students from various semesters or academic periods, from 2020 to 2023, of the Pedagogy of Language and Literature Degree of the Faculty of Philosophy, Letters and Educational Sciences of the Central University of Ecuador. These students were distributed into 14 groups. 218 of these students belong to the 7 experimental groups, which follow a technology-enriched teaching method, and 197 students belong to the 7 groups designated as the control group, which follow a traditional teaching method. 27 subjects were removed from the analyses, 11 from the experimental group and 16 from the control group, for not having scores on all variables. 68.2% reported being female and 31.8% male. The minimum university entrance scores for students of the Pedagogy of Language and Literature Degree were 865/100 (UCE, 2019) for the 2019-2020 cycle, 821/1000 (UCE, 2020) for the 2020-2020 cycle, and 796/100 (UCE, 2021) for the 2021-2021 cycle.

Variables

The *Group* is considered the independent variable. Two groups are considered: 1 = Experimental and 2 = Control. The experimental group is the one for which the intervention was designed with the application of the technology-supported Instructional Design, and the control group is the one that follows a traditional teaching method, without technology support.

The *University Entrance Score* is used as the control variable. The Ecuadorian education system establishes that access to the University is regulated through an admission exam. This test, applied online by the Secretariat of Higher Education, Science, Technology and Innovation of Ecuador, has a scale of 0 to 1000 points. The test evaluates abilities and competencies: Verbal Aptitude, Numerical Aptitude, Logical Reasoning, and Attention and Concentration; as well as knowledge of Mathematics, Language and Literature, Natural Sciences, and Social Sciences (SENESCYT, 2020). This test accounts for 60% of the score, and the remaining 40% is for academic background.

The *Diagnostic Assessment (Pretest)* is considered a dependent variable. It is carried out at the beginning of the research in each group. The pretest is based on a structured-base, objective-type test, for which a 90-question questionnaire is generated, addressing the study units called fundamentals and theories of evaluation, evaluation planning, construction of evaluation instruments, and evaluation regulations in Basic General Education and Unified General Baccalaureate of the Ecuadorian educational system. It includes questions in various formats: simple, column matching, completion, ordering, selection of elements and context; taxonomic levels: knowledge, comprehension, and application; and with low, medium, and high difficulty levels. It is scored on a scale of 0 to 20 points and is not taken into account for calculating the final course grade.

Global Academic Achievement is the result of the learning of knowledge, skills, and attitudes that the student has achieved as a product of the teaching-learning process. The score is composed of the sum of the following activities: the Theoretical Exam at the end of the semester – (Posttest), which is applied to check the learning of conceptual content, using a structured-base test similar to the pretest. The Practical Exam, where procedural content is evaluated, through the construction of an evaluation instrument according to the official curriculum of the Ecuadorian educational system. Evaluation of *Individual Activities*, such as construction of graphic organizers, individual tests of the various study units, class participation. Evaluation of *Group Activities*, such as collaborative construction of graphic organizers, group presentations, construction of evaluation instruments, application of technological tools for evaluation. The weight given to each of the activities in the global achievement is: individual activities 35%, group activities 30%, theoretical exam 10%, and practical exam 25%. The course academic achievement score is obtained on a scale of 0 to 20 points.

Procedure

The procedure for obtaining data and implementing the instructional design follows these steps: Authorization for the execution of the research was requested from the Faculty of Philosophy and ethical approval was obtained from the University of Alicante following the established procedure, obtaining the approval of the University's Ethics Committee.

For the intervention in the experimental group, the course for the subject *Evaluation of Learning* was designed based on the technology-supported instructional design. That is, an intervention was designed to manipulate the independent variable called technology-supported instructional design and measure the effects on the dependent variable called academic achievement. For this purpose, meaningful learning experiences were designed, incorporating different technologies to foster communication, interaction, and collaboration. For example, the didactic sequence generated to develop the ability to design

structured-base tests with Moodle quizzes can facilitate more agile and deeper learning. That is, the planned and pedagogically grounded integration of technology so that students achieve the learning outcomes set out in the subject syllabus will promote new ways of teaching, learning, and evaluating.

The course for *Evaluation of Learning* was designed on the MOODLE platform based on the ADDIE Instructional Design model: a) *Analysis Phase*: This involved studying training needs to establish learning objectives and student characteristics. The context in which the course would be executed was analyzed; b) *Design Phase*: A course structure, activities, resources, materials, order of appearance, times, and evaluation instrument were established, and harmonization between the formal and official structure of the University and the proposed elements for the intervention was established; c) *Development Phase*: Instructional materials for the different units, labels, activities, resources, and evaluations were prepared and uploaded to the Moodle platform, which had to be reviewed and tested prior to its operation; d) *Implementation Phase*: The operation of the course began according to the calendar established by the University, activities were worked on, and the proposed resources for each unit were used. This phase involved applying the designed instructional plan in the real educational setting; e) *Evaluation Phase*: An initial, formative, and summative evaluation process was established that allowed for measuring the learning achieved throughout the development of the design. The results were used to iteratively refine the design for future iterations.

The activities for the intervention in the experimental group were designed based on the SAMR integration model. Individual and group activities were implemented in the Institution's Virtual Classroom based on MOODLE. The ZOOM Videoconference system was used. In the development of this course, two virtual classrooms were considered, one with the student role and another with the teacher role. In the first, where they participate as students, they execute the activities designed by the teacher (e.g., answering an online quiz designed by the subject teacher), and in the second, where they participate as teachers, they design the online quiz for the area of knowledge of their degree. This allows them to relate reality to what they are learning in class. The intervention was repeated for the seven periods (academic semesters).

The procedure followed in classes using traditional teaching consisted of providing the base and supplementary text with handouts that must be read both in class and at home. Expository classes with details of the content to be addressed, assign activities as autonomous work for them to apply what they have learned. For example, a structured-base test is designed and submitted in print to be graded, and feedback is given generally in class. In general, communication, interaction, and collaboration are low. In the traditional method: a) the student's role is passive, listening and taking notes; b) the teacher's role is that of a transmitter of information; c) the teaching method is expository, demonstrative;

d) resources focus on textbooks, whiteboard, notebooks, and oral exposition; e) the learning environment is face-to-face, in the physical classroom; f) communication is predominantly unidirectional, teacher to student; g) the pace of learning is uniform for the group of students; h) assessment is traditional, focused on exams, usually at the end.

The traditional approach contrasts with the technology-enriched teaching method used in this work, in which: a) the student's role is active, exploratory, collaborative, reflective with the support of digital media; b) the teacher's role is that of a facilitator and guide of learning, designer of learning experiences supported by technologies; c) the teaching method is interactive, collaborative, supported by problem-solving; d) resources consist of virtual platforms, videos, collaborative tools; e) the learning environment is face-to-face or hybrid, flexible, dynamic; f) communication is multidirectional, teacher-student-student-content-technology; g) the pace of learning is flexible, personalized, adapted to the rhythms and styles of the students; h) assessment is formative, continuous, with immediate feedback supported by digital tools.

Data Analysis

This work uses a quasi-experimental design, with not entirely equivalent control groups, with measures before and after the instructional intervention. That is, a technology-based instructional design was applied in some groups, while in other groups an instructional design that made minimal or no use of these technological resources was followed. Various data analysis techniques are used: descriptive statistical techniques, repeated measures ANOVA analysis of variance, with the pretest-posttest variable as the within-subjects or repeated measure variable, and the group variable (experimental and control) as the between-subjects variable; furthermore the assumptions of covariance analysis are also checked, and the university entrance test, which evaluates ability and prior knowledge, is used as a covariate to control for the possible effect of general ability and prior knowledge on the different aspects of academic achievement, independently of the effect of the technology-enriched teaching method. All analyses are performed with the SPSS Version-28 program.

RESULTS

Descriptive Analysis

Table 1 presents the descriptive statistics, mean and standard deviation, of the experimental and control groups in each of the measured variables.

Small differences in the means of the experimental and control groups can be observed in each of the variables, in favor of the experimental group.

The standard deviations are also very similar between the experimental and control groups for the three variables measured.

Table 1
Descriptive statistics of each group, experimental and control, in each of the variables

Variable	Group	N	Mean	Standard deviation
Pretest Assessment	Experimental	207	10.45	2.52
	Control	181	10.08	2.63
Academic achievement	Experimental	207	17.79	1.06
	Control	181	16.65	1.30
University Entrance Score	Experimental	207	843.36	47.77
	Control	181	837.10	47.23

Analysis of variance taking the final academic achievement assessment as result

Table 2 offers a summarized view of the results of the repeated measures ANOVA, using a mixed between/within-subjects design, considering the score in final academic achievement as the dependent variable.

Table 2.
Summary of the univariate ANOVA between-within-subjects considering the pretest as the within-subject measure and academic achievement as the dependent variable.

Source	Type III Sum of Squares	df	Mean Square	F	P	η^2 partial	Observed Power ^a
Factor1	13402.05	1	13402.05	3907.52	.001	.88	1
Factor1*Group	48.28	1	48.28	14.07	.001	.03	.96
Error (Factor1)	1766.35	515	3.43				
Group	135.71	1	135.71	23.39	.001	.04	.99
Error	2988.00	515	5.80				

a. Estimated using $\alpha = .05$

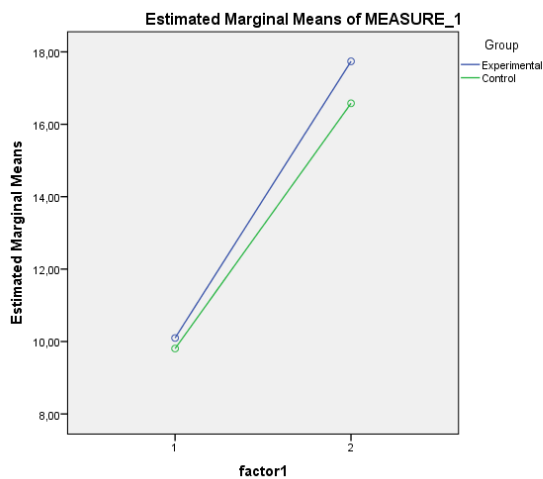
The within-subjects effect (Factor1) is significant ($F = 3907.52$; $p = .001$), indicating that both groups together increase their scores from pretest to posttest. The Group factor, the difference between the experimental group and the control group, considering both

measures jointly before and after the instructional intervention, is also significant ($F = 23.39, p = .001$). The interaction, Factor 1*Group, is also significant ($F = 14.07; p = .001$), which indicates that the differences between the experimental and control groups are distinct in the pre-test and post-test, due to the effect of the instructional treatment.

The interpretation of the interaction effect is observed in Figure 1 and the mean data in Table 1. In the pre-test, the experimental and control groups have similar scores, with the experimental group slightly higher than the control group, while in the post-test the experimental group obtains a higher score than the control group. The estimation of the parameters offered by SPSS shows that in the diagnostic pretest the means of both groups, experimental and control, are not significant ($t = 1.19, p = .23$), but they are significant after the instructional treatment, in favor of the experimental group ($t = 10.74, p = .00$).

Figure 1.

Graphical representation of the interaction between the pretest scores and the final academic achievement score, in the experimental and control groups.



However, although there are significant effects of the technology-enriched teaching method on academic achievement at the end of the semester, the size of these effects, as indicated by the partial eta squared statistic, is quite moderate. The teaching method enriched with new technologies, applied in the experimental group, produces an improvement in achievement that is around 4%.

Analysis of variance taking academic achievement scores as result and university entrance scores as a covariate.

Firstly, the assumptions of the covariance analysis are examined: 1) the existence of a relationship between the covariate and the dependent variable, for which simple regression analysis is used, taking achievement as the criterion variable and the entrance score as the predictor variable, whose effect is expected to be significant; 2) the homogeneity of regression slopes, by checking the interaction between the covariate -entrance score -, and the independent variable, the experimental and control groups, whose effect should not be significant, demonstrating that the slopes are similar in both groups; 3) the independence of the covariate and the treatment effect, expecting no significant differences in the entrance score between the experimental and control groups.

The results of the examination of the assumptions of the covariance analysis show that: 1) the value of the regression slope of the entrance score against the dependent variable is significant (Beta = .14, $p = .003$); 2) the interaction between the entrance score and the independent variable, Group, was not significant ($F = .80$, $p = .37$); 3) the differences between the means of the entrance scores were not significant between the experimental group and the control group ($t = 1.55$, $p = .12$).

Once the three assumptions for carrying out the covariance analysis are met, the entrance score is included as a covariate in the repeated measures ANOVA.

Table 3 offers a summarized view of the results of the repeated measures ANOVA, within-between-subjects, considering the score in academic achievement as the dependent variable, and the university entrance scores as a covariate.

As can be seen in Table 3, the significant effect of the Factor 1*Group interaction is maintained ($F = 10.27$; $p = .001$) after controlling for the possible effect of ability and prior knowledge on academic achievement scores. This effect indicates the influence of the technology-enriched teaching method on achievement scores.

Table 3.

Summary of the univariate ANOVA within-subjects considering academic achievement scores as the result, and university entrance scores as a covariate.

Source	Type III Sum Squares	df	Mean Square	F	p	Partial η^2	Observed Power ^a
Factor1	56.49	1	56.49	19.47	.001	.05	.99
Factor1*Access	4.27	1	4.27	1.47	.220	.01	.22
Factor1 * Group	29.81	1	29.81	10.27	.001	.03	.89
Error (Factor1)	1117.07	385	2.90				

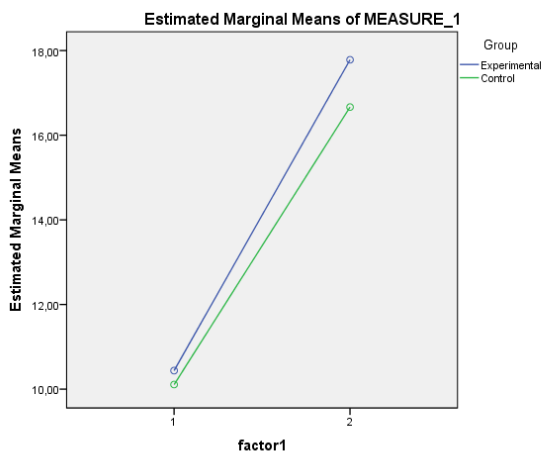
Source	Type III Sum Squares	df	Mean Square	F	P	Partial η^2	Observed Power ^a
Access	39.98	1	39.98	7.91	.002	.02	.80
Group	100.69	1	100.69	19.92	.001	.05	.99
Error	1945.84	385	5.05				

a. Estimated using $\alpha = .05$

As observed in the graphical representation of the group means (Figure 2), the groups that followed a technology-enriched instructional design obtained very similar scores to the control group that followed a more traditional teaching method in the pretest, but achieved higher scores in the academic achievement at the end of the course. The estimated parameters show that there are no differences between the experimental and control groups in the pretest ($t = 1.26, p = .20$), but there are in the posttest ($t = 9.35, p = .00$) in favor of the technology-enriched group.

Figure 2.

Graphical representation of the interaction between the pretest measure of theoretical knowledge and academic achievement with the group, experimental and control, once controlling for the effect of university entrance scores.



Covariates appearing in the model are evaluated at the following values: Access Score = 840,44

In sum, when the effect of the abilities and prior knowledge used to access the university is controlled, by including the entrance scores as a covariate, the same effects of the technology-enriched instruction on academic achievement are reached.

DISCUSSION AND CONCLUSIONS

The objective of this work was to evaluate the effects of the application of a technology-supported instructional design on academic achievement at the end of the course for different groups of Ecuadorian students, once the effect of general ability and prior knowledge evaluated by the Ecuadorian university entrance examination was statistically controlled.

The results show a positive effect of the technology-enriched method, which follows an instructional design based on constructivist and situational principles, on the global academic achievement evaluated at the end of the semester in students of the Pedagogy of Language and Literature Degree of the Faculty of Philosophy, Letters and Educational Sciences of the Central University of Ecuador. This methodology uses the ADDIE model as an instructional model and SAMR as a model of educational integration of technologies. Thus moving from traditional education to education mediated by technological advances, still under development and evaluation (Lévy and Zapata-Ros, 2023).

This work demonstrates the effectiveness of a technological instructional design based on theoretical principles on different academic achievement outcomes of university students in teacher training, in line with what is established by various authors (Hernández-Sellés et al., 2023; Jonassen, 2000). However, the effect of the technology-enriched teaching method is moderate, in line with literature reviews on the effects of the use of new technologies on academic achievement in non-university education stages. These works highlight the limitations of technology, by itself, for improving students' academic achievement, and the need to integrate this technology into an instructional design that enables the development of global learning environments that favor achievement (Hattie, 2009; 2023; Reitmann and Aditomo, 2013).

Instructional design has been evolving in recent years towards the incorporation of technology into the educational process, both from the theoretical field (Jonassen, 2000; Reigeluth, 2016; Spector, 2016) and practical field due to the pandemic (Morales- González, 2022). Improving the quality of higher education is a priority for achieving the scientific and technological development of future teachers. For this purpose, the enriched technological design provides an innovative tool that allows the immersion of students in new paradigms of interpretation and transformation of reality, which facilitate comprehension and learning (Hodges and Kirschner, 2024).

In summary, the application of the technology-enriched teaching method improves academic achievement. The technology-enriched teaching methodology, based on the ADDIE instructional design model and the SAMR educational integration model, is shown to be effective for improving the academic achievement of the students who participated in

the educational process of the Pedagogy of Language and Literature Degree of the Faculty of Philosophy, Letters and Educational Sciences of the Central University of Ecuador.

A limitation of this study is that it is circumscribed to a specific population; it is necessary to apply this instructional resource to new students and degrees to establish its usefulness as a teaching method in higher education.

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Disclosure Statement

No potential conflict of interest was reported by the author(s).

Data Availability Statement

Study data are available from the corresponding author upon request.

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