



Active Digital Classroom: Pedagogical Integration of Technological Tools to Strengthen Learning in Higher Education

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ABSTRACT. This applied study evaluated the Active Digital Classroom strategy, a pedagogical intervention that integrates a learning management system, interactive questions, collaborative production, and formative assessment with immediate feedback. A mixed-methods approach with a predominantly quantitative emphasis was adopted, following a quasi-experimental pretest-posttest design with a comparison group. Sixty university students enrolled in a Research Methodology course were distributed into an experimental group ($n = 30$) and a comparison group ($n = 30$). The intervention ran for eight weeks using Moodle, Mentimeter, Padlet, and Google Forms. Academic performance, engagement, participation, activity completion, and student perception were measured. The experimental group increased its performance from 65.06 to 76.54 points, compared with a change from 64.92 to 69.84 in the comparison group; the difference in gains was significant, $t(58) = 3.56$, $p < .001$, $d = 0.92$. Significant effects were also found for engagement ($d = 0.81$), participation ($d = 1.54$), and completion ($d = 0.78$). The 36-item final questionnaire showed high internal consistency ($\alpha = 0.899$). The findings show that a pedagogically planned integration of digital tools can strengthen university students' learning, participation, and overall experience.

KEYWORDS- active learning, digital classroom, educational technology, formative assessment, student engagement.

1. INTRODUCTION

1.1 Context and Problem

The digital transformation of higher education has broadened access to virtual platforms, communication applications, assessment systems, and multimedia resources; however, the availability of technology does not by itself guarantee a transformation of teaching. UNESCO [1] warns that the evidence on the added value of educational technology is heterogeneous and that decisions must keep the student at the center of pedagogical design. Along a convergent line, the OECD [2] distinguishes between digital transition and digital transformation: using platforms to reproduce traditional practices is not the same as redesigning the learning experience.

In the university classroom, a recurring difficulty is that technologies are incorporated merely as support for lecturing — slides, file distribution, or assignment collection — a functional use that nonetheless preserves a teacher-centered, transmission-based pattern and leaves little room for continuous questioning, collaboration, immediate feedback, and student production. From the Technological Pedagogical Content Knowledge (TPACK) framework, Mishra and Koehler [3] argue that meaningful technology integration requires articulating content, pedagogical, and technological knowledge, avoiding treating the tool as a component independent of instructional design. Recent evidence further reinforces the need to evaluate pedagogical design rather than the mere presence of technology: Jacob and Centofanti [4] found no significant improvement in assessment outcomes when interactive H5P resources had low usage levels, whereas Zainuddin et al. [5] observed better performance and higher engagement when interactive questions were distributed throughout the class and accompanied by dialogue and feedback. This contrast suggests that the effect depends on how technology structures cognitive and social activity, not merely on its availability.

The central problem, then, lies in the gap between technological availability and pedagogical impact: classrooms may have connectivity, projectors, smartphones, and platform access, yet still show low participation and a predominance of receptive activities. This situation makes it difficult to detect conceptual errors during class, reduces participation opportunities for students less inclined to speak up, and limits the formative monitoring of learning. Active Digital Classroom is proposed as an applied response to this gap: a strategy that combines technological resources with active learning and formative assessment, whose unit of analysis is not the application used but the pedagogical sequence — activating prior knowledge, posing questions, organizing application tasks, making responses visible, promoting interaction, and providing feedback before a summative assessment.

1.2 Theoretical Foundations

The conceptual model of Active Digital Classroom draws on four bodies of literature. First, the DigCompEdu digital competence framework [6] organizes educators' digital competence into six areas — professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence — of which the strategy is most closely linked to teaching and learning, assessment, and empowerment. Second, active learning encompasses approaches in which students perform relevant cognitive actions during the session, such as solving problems, answering questions, explaining, comparing, and producing; the meta-analysis by Freeman et al. [7], based on 225 studies of university STEM courses, found an overall advantage of active learning over traditional lecturing in academic performance.

Third, the principle of short prior micro-content is linked to the flipped-classroom model: Aydin and Demirel [8] found better academic success outcomes in a flipped-classroom model compared with a traditional condition, supporting the idea of freeing class time for application and discussion through prior access to brief resources. Fourth, formative assessment conceives digital questions not as final tests but as mechanisms that make comprehension visible while learning is occurring; immediate feedback allows misconceptions to be corrected before they become consolidated. Nevertheless, digital integration also carries risks — uneven connectivity, distraction, application overload, and superficial use — and the systematic review by Akpen et al. [9] shows that the impact of online learning on performance and engagement is variable and depends, among other factors, on the quality of the tools, connectivity, motivation, and interaction with instructors and peers. The conceptual model therefore assumes that a planned pedagogical integration increases opportunities for response, interaction, and feedback; these opportunities strengthen participation and engagement; and sustained practice together with early error correction favors performance and completion.

1.3 Objectives and Hypotheses

The general objective of the study was to evaluate the contribution of the Active Digital Classroom strategy, based on the pedagogical integration of technological tools, to strengthening the learning of university students. Specifically, the study sought to: (a) determine the changes produced in academic performance before and after the intervention; (b) compare students' academic engagement before and after applying the strategy; (c) identify variations in student participation during academic activities; (d) measure the level of activity completion before and after the application; and (e) describe students' perception of the access, interaction, feedback, motivation, and usefulness of the Active Digital Classroom.

The research hypothesis (H1) posited that the application of the Active Digital Classroom strategy produces statistically significant improvements in academic performance, engagement, participation, and activity completion compared with a conventional methodology, against the null hypothesis (H0) that such application produces no statistically significant differences in the selected learning indicators.

2. METHOD

2.1 Design and Approach

The study was applied in nature, aimed at intervening in a concrete educational situation through a strategy designed to improve learning. A mixed-methods approach with a predominantly quantitative emphasis was adopted: learning indicators were analyzed statistically and open-ended responses from the final questionnaire were organized through descriptive thematic categories. The design was quasi-experimental, with pretest-posttest measurement and non-equivalent groups: two natural sections took the same content and assessments, one as the experimental group (Active Digital Classroom) and the other as the comparison group (conventional methodology supported by lecturing, digital materials, and routine assignments). The absence of random assignment required verifying the initial equivalence of the groups and acknowledging the potential influence of extraneous variables.

2.2 Participants

The study involved 60 university students enrolled in a Research Methodology course at a university in Alto Parana, Paraguay, distributed into an experimental group ($n = 30$) and a comparison group ($n = 30$). Sampling was of the census type, since complete sections were used. No attrition was recorded, so all cases have both pretest and posttest measurements.

2.3 Variables and Instruments

The independent variable was the implementation of the Active Digital Classroom strategy. The main dependent variable, university learning, was operationalized through four dimensions: academic performance, engagement, participation, and activity completion. Student perception of the digital active experience was considered a complementary variable. Five sources of information were used: (a) a parallel pretest-posttest knowledge test (two 20-item forms, 0-100 score); (b) a pre-post engagement scale on a 1-5 Likert format; (c) a participation record expressed as the percentage of response and intervention activities completed; (d) a completion record expressed as the percentage of assignments submitted on time; and (e) a 36-item perception questionnaire, administered at the close of the intervention to the experimental group, organized into six dimensions (access and digital competence, active participation, interaction and collaboration, formative assessment and feedback, engagement and motivation, and perceived usefulness and learning) with two final open-ended questions. The internal consistency of the questionnaire, estimated using Cronbach's alpha, was 0.899, indicating high internal homogeneity.

2.4 Intervention Procedure

The Active Digital Classroom intervention ran for eight weeks. Moodle served as the environment for organizing content and assignments; Mentimeter was used to activate prior knowledge and collect real-time responses; Padlet enabled collaborative production and the sharing of contributions; and Google Forms supported formative assessment through brief quizzes with feedback. The weekly sequence combined diagnosis and baseline measurement (week 1), activation and response (week 2), micro-content (week 3), collaboration (week 4), application (week 5), formative assessment (week 6), integrative production (week 7), and closure with the posttest and perception questionnaire (week 8). The general procedure comprised obtaining institutional authorization, informing students and collecting informed consent, administering the pretest and baseline measurements, implementing the strategy with fidelity monitoring, administering the posttest and the final questionnaire, cleaning and coding the data, and conducting the statistical analysis and the categorization of open-ended responses.

2.5 Data Analysis

Means, standard deviations, and percentages were calculated to describe the indicators. Initial equivalence between groups was checked using the independent-samples Student's t-test. For each group, the paired-samples Student's t-test was used to compare pretest and posttest scores, and the differential effect of the intervention was evaluated by comparing gain scores between groups using an independent-samples t-test, reporting Cohen's d as the effect size. Prior to testing, the normality of gain scores was verified using the Shapiro-Wilk test and the homogeneity of variances using Levene's test. The significance level was set at $\alpha = .05$. Open-ended responses from the final questionnaire were organized through descriptive thematic categorization, estimating the frequency and percentage of students who mentioned each category.

2.6 Ethical Considerations

Participation was voluntary, with the possibility of withdrawing without academic consequences. Information was analyzed in aggregate form and kept separate from the regular grading system. Foreseeable risks were minimal and related to response time, connectivity, and possible discomfort with the questionnaire; the intervention included alternative access arrangements for students facing technological difficulties.

3. RESULTS

3.1 Initial Equivalence and Statistical Assumptions

For all four indicators, Shapiro-Wilk tests applied to gain scores yielded p values above .05, and Levene's test showed no evidence of variance heterogeneity (Table 1); parametric tests were therefore used for the planned comparisons. Likewise, no statistically significant differences were detected between groups at baseline ($p > .20$ for all four indicators), indicating that, for the indicators observed, the baseline was comparable between the experimental and comparison groups.

Table 1. Verification of Statistical Assumptions and Initial Equivalence Between Groups

Indicator	Shapiro exp. (p)	Shapiro comp. (p)	Levene (p)	Initial t(58)	Initial p
Academic performance	0.117	0.090	0.881	0.06	0.950
Academic engagement	0.714	0.434	0.810	-0.08	0.937
Academic participation	0.071	0.934	0.582	-1.21	0.232
Activity completion	0.438	0.385	0.982	0.41	0.686

3.2 Academic Performance

The experimental group increased its academic performance from $M = 65.06$ ($SD = 7.90$) to $M = 76.54$ ($SD = 7.91$), a mean gain of 11.48 points, while the comparison group went from $M = 64.92$ ($SD = 9.18$) to $M = 69.84$ ($SD = 9.45$), a gain of 4.92 points (Fig. 1). The comparison of gain scores between groups showed $t(58) = 3.56$, $p < .001$, $d = 0.92$, a large effect size suggesting a substantive advantage of the intervention in the scenario evaluated.

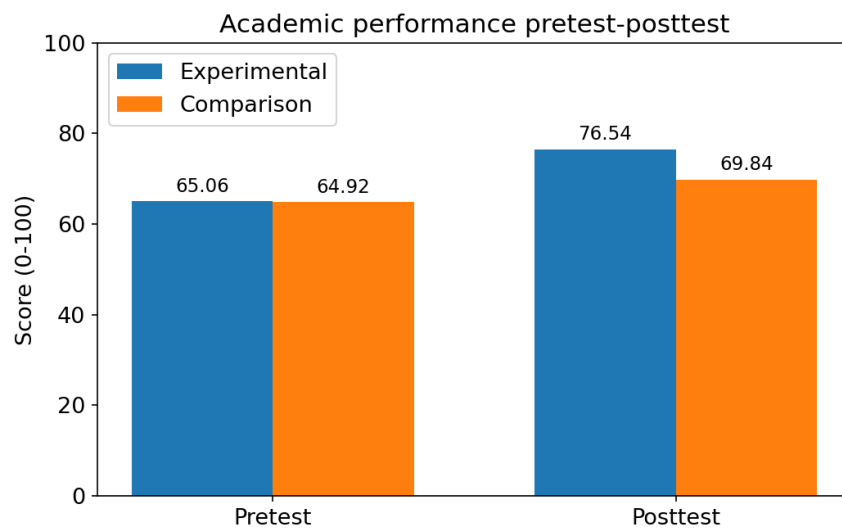


Fig. 1. Mean academic performance before and after the intervention, by group.

3.3 Academic Engagement

Academic engagement in the experimental group increased from 3.06 to 3.61 points on a 1-5 scale, while the comparison group increased from 3.07 to 3.30 (Fig. 2). The difference in gains was significant, $t(58) = 3.14$, $p = .003$, $d = 0.81$, suggesting a large effect on attention, effort, and academic motivation.

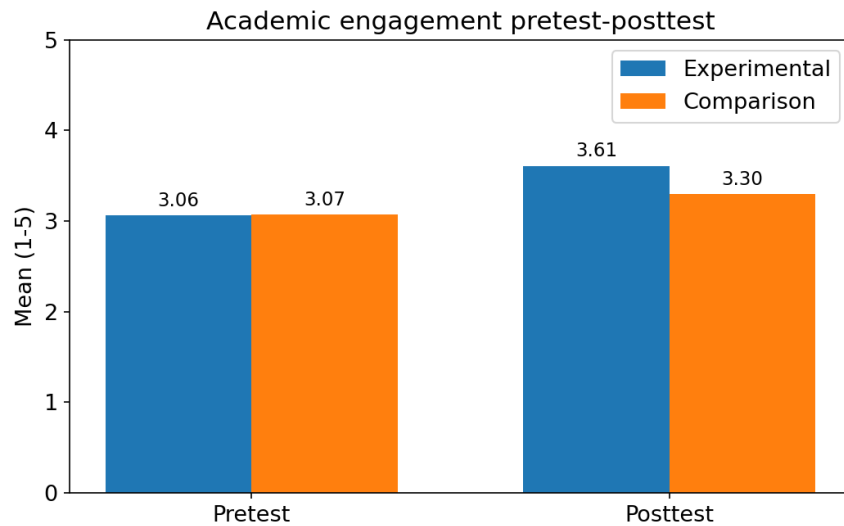


Fig. 2. Mean academic engagement before and after the intervention, by group.

3.4 Academic Participation

Participation in the experimental group increased by 24.01 percentage points, from 47.04% to 71.05%, compared with an increase of 5.29 points in the comparison group, from 50.25% to 55.54% (Fig. 3). The difference in gains was $t(58) = 5.96$, $p < .001$, $d = 1.54$, the largest effect among the indicators evaluated.

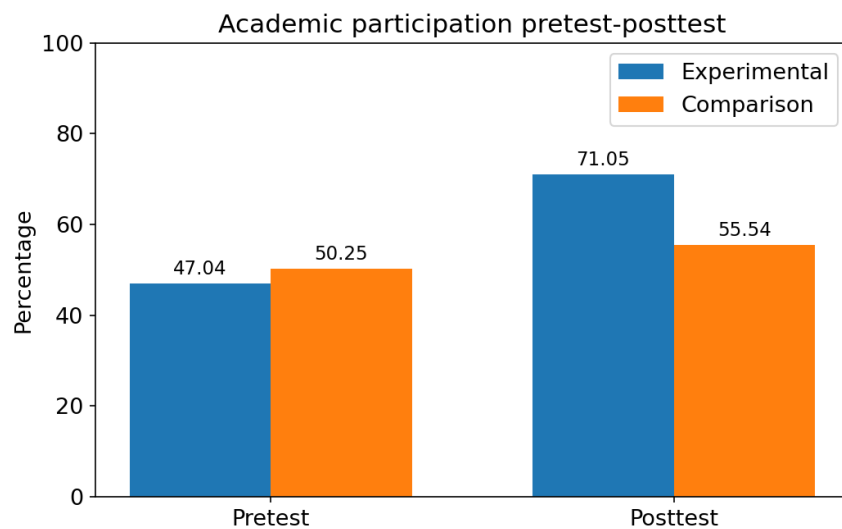


Fig. 3. Mean academic participation before and after the intervention, by group.

3.5 Activity Completion

Activity completion in the experimental group increased from 70.37% to 83.55%, equivalent to a gain of 13.18 points, while the comparison group increased from 69.28% to 75.56%, a gain of 6.28 points (Fig. 4). The comparison of gains showed $t(58) = 3.02$, $p = .004$, $d = 0.78$, a moderate-to-large effect.

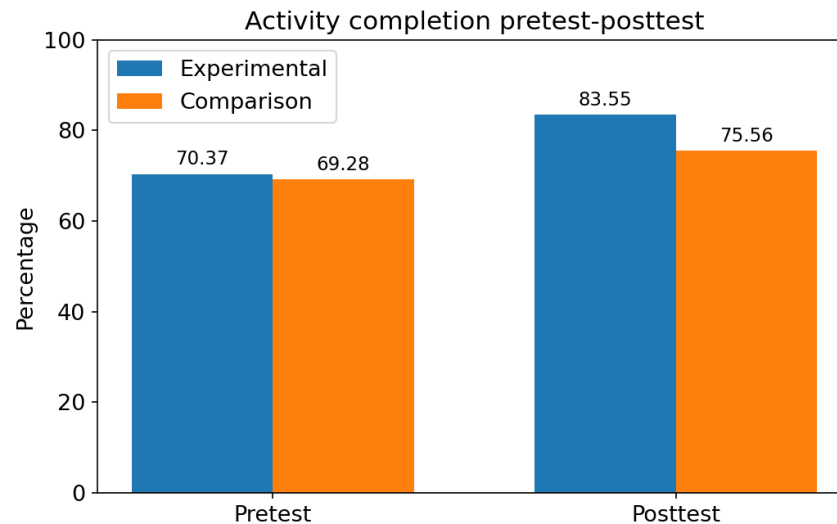


Fig. 4. Mean activity completion before and after the intervention, by group.

3.6 Summary of Effect Sizes

Both groups improved on all four indicators evaluated, a pattern that is expected when both receive instruction over the period; however, the evidence relevant to the research hypothesis does not consist merely in the experimental group improving, but in the magnitude of its change being significantly greater than that of the comparison group (Table 2). Because all four gain comparisons were statistically significant, with effect sizes ranging from $d = 0.78$ to $d = 1.54$, the results lead to rejecting the null hypothesis (H_0) and supporting the research hypothesis (H_1).

Table 2. Comparison of Gains Between Groups and Effect Size

Indicator	Exp. gain	Comp. gain	t(58)	p	d	Magnitude
Academic performance	11.48	4.92	3.56	< .001	0.92	Large
Academic engagement	0.55	0.23	3.14	.003	0.81	Large
Academic participation	24.01	5.29	5.96	< .001	1.54	Large
Activity completion	13.18	6.28	3.02	.004	0.78	Moderate-high

3.7 Student Perception and Final Questionnaire Reliability

The perception questionnaire, comprising 36 items across six dimensions, showed high internal consistency ($\alpha = 0.899$). The dimension with the highest mean was Active participation ($M = 4.36$; 97.8% favorable responses), followed by Formative assessment and feedback ($M = 4.31$; 96.7%) and Perceived usefulness and learning ($M = 4.27$; 96.1%). The lowest-scoring dimension was Access and digital competence ($M = 4.02$; 91.7%), although it remained at a favorable level (Fig. 5; Fig. 6; Table 3). This pattern is consistent with an intervention that generates positive pedagogical effects while remaining subject to technological constraints such as connectivity, available devices, and digital skills.

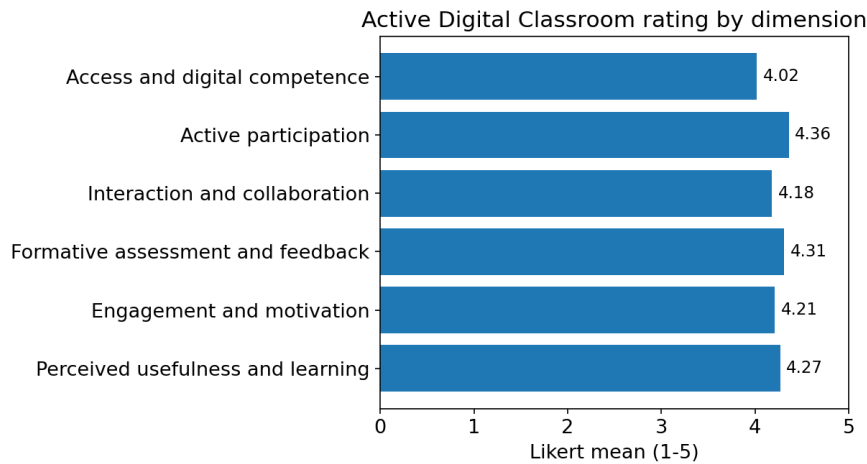


Fig. 5. Final questionnaire means by dimension.

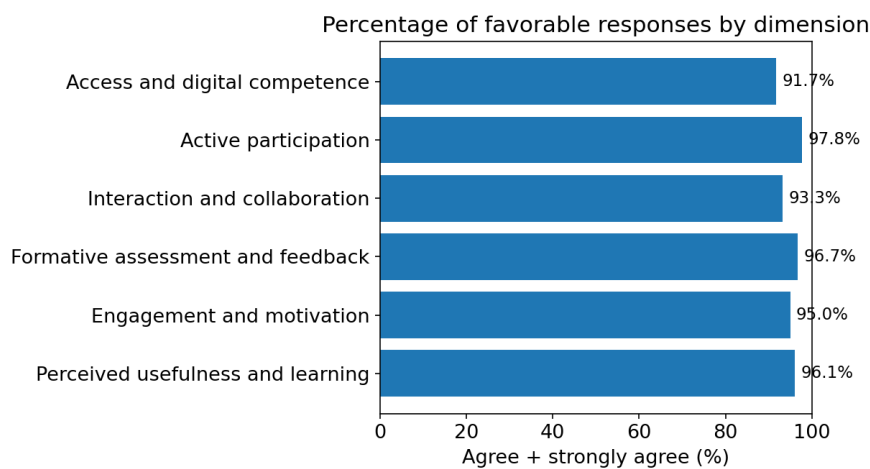


Fig. 6. Percentage of favorable responses by dimension.

Table 3. Means and Percentage of Favorable Responses by Final Questionnaire Dimension

Dimension	Mean	Favorable responses (%)	Interpretation
Access and digital competence	4.02	91.7%	Favorable
Active participation	4.36	97.8%	Very favorable
Interaction and collaboration	4.18	93.3%	Favorable
Formative assessment and feedback	4.31	96.7%	Very favorable
Engagement and motivation	4.21	95.0%	Very favorable
Perceived usefulness and learning	4.27	96.1%	Very favorable

3.8 Qualitative Results

Open-ended questions from the final questionnaire identified the categories most frequently perceived among the 30 students in the experimental group: immediate feedback (60.0%), greater opportunity for participation (56.7%), peer collaboration (43.3%), and organization and dynamism of the activity sequence (36.7%). Among the difficulties mentioned were occasional connectivity problems (30.0%) and the risk of distraction associated with using multiple applications (20.0%) (Table 4). The integration of quantitative and qualitative findings suggests that the main perceived contribution of Active Digital Classroom was not the use of applications per se, but the opportunity to receive feedback, respond more frequently, and work collaboratively, while the difficulties concentrate on access conditions and the need to avoid tool overload.

Table 4. Categories Identified in Open-Ended Responses From the Experimental Group (n = 30)

Category	Frequency (n)	% of 30
Immediate feedback	18	60.0%
Greater opportunity for participation	17	56.7%
Peer collaboration	13	43.3%
Organization and dynamism of activities	11	36.7%
Occasional connectivity problems	9	30.0%
Risk of distraction from multiple applications	6	20.0%

4. DISCUSSION

The pattern of results is consistent with the literature that attributes value to active learning and integrated formative assessment. The largest effect was observed for participation, a dimension directly affected by polls, questions, collaborative boards, and short tasks, which is consistent with Zainuddin et al. [5], who showed that questions distributed throughout instruction can sustain attention, reasoning, and dialogue. The improvement in academic performance, in turn, should be interpreted as the result of a pedagogical chain rather than an automatic effect of the applications used: Freeman et al. [7] documented that active learning can improve performance in higher education, and Aydin and Demirer [8] found academic advantages in a flipped-classroom setting, while the lack of improvement associated with H5P resources reported by Jacob and Centofanti [4] warns that interactive tools have little value if students do not engage with them.

The favorable assessment of feedback and perceived usefulness also aligns with the review by Akpen et al. [9], which highlights the weight of interaction, tool quality, connectivity, and motivation in students' performance and engagement in digital environments. Accordingly, an eventual institutional model should minimize the number of platforms used, guarantee access alternatives for students with limited connectivity, and train instructors in pedagogical design — not solely in the technical handling of tools — in line with the teaching, assessment, and empowerment areas of the DigCompEdu framework [6]. The findings should nonetheless be interpreted in light of the study's limitations: the quasi-experimental design with non-equivalent groups does not allow for as rigorous a control of extraneous variables as a randomized experiment, the sample was confined to a single course and institutional context, and the eight-week period does not allow the medium-term sustainability of the observed effects to be estimated.

5. CONCLUSION

The findings of this applied study indicate that the Active Digital Classroom strategy — understood as a pedagogically planned integration of a learning management system, interactive questions, collaborative production, and formative assessment — was associated with significantly greater gains than a conventional methodology in academic performance ($d = 0.92$), engagement ($d = 0.81$), participation ($d = 1.54$), and activity completion ($d = 0.78$), in addition to a favorable student rating across all six dimensions of the final questionnaire ($\alpha = 0.899$). These findings do not allow the effect to be attributed to any single tool; the central factor of the model is the instructional sequence that articulates objectives, interaction, assessment, and feedback, which supports the research hypothesis (H1) over the null hypothesis.

Key limitations include the quasi-experimental design without random assignment, the confinement of the study to a single course and academic term, and the absence of a follow-up measurement after the intervention. Uneven connectivity and application overload are, in addition, implementation risks that an active digital strategy must address through operational simplicity, accessibility, and technical support. As lines for application and extension, it is recommended to implement the model initially in pilot courses before scaling it institutionally; to train instructors in active learning, formative assessment, and TPACK design in addition to platform management; to use a limited and stable set of tools; to establish participation alternatives for students with restricted connectivity; and to extend the study over a full semester and across different degree programs, complementing the quantitative results with interviews or focus groups that can explain why certain activities generate greater or lesser participation.

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