Ecuacientífica
ISSN: 3091-1796
Vol. 4 No. 9 PP. 65-74
DOI: https://doi.org/10.56519/5wxahf27
Mayo 2026

TRANSFORMACIÓN DEL APRENDIZAJE ANATÓMICO MEDIANTE LA IMPLEMENTACIÓN DE LA TECNOLOGÍA ANATOMAGE

REDEFINING ANATOMY EDUCATION THROUGH THE INTEGRATION OF ANATOMAGE TECHNOLOGY

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Fecha de recepción: 12/02/2026 / Fecha de aceptación: 21/04/2026 / Fecha de publicación: 12/05/2026

RESUMEN: La enseñanza de la anatomía en medicina requiere estrategias que faciliten la comprensión estructural y la aplicación clínica del conocimiento. En este contexto, el presente estudio tuvo como objetivo analizar los efectos académicos de integrar la tecnología Anatomage en el proceso formativo de estudiantes de Medicina. Se desarrolló un diseño cuantitativo con evaluación antes y después de la intervención, incorporando análisis estadístico de desempeño y medición de percepción estudiantil. La intervención se implementó durante cuatro semanas mediante actividades de exploración anatómica tridimensional y trabajo colaborativo orientado a la correlación morfofuncional. Los resultados evidenciaron mejoras en el rendimiento académico y en la precisión para identificar relaciones espaciales complejas. En la discusión se interpreta que el uso sistemático de visualización digital favorece la construcción activa del conocimiento. Se recomienda integrar tecnologías anatómicas interactivas como complemento estructural en los programas de ciencias de la salud.

Palabras clave: *Simulación anatómica digital, competencias espaciales, aprendizaje aplicado*

ABSTRACT: Anatomy education in medical training requires instructional approaches that enhance structural comprehension and support the clinical application of knowledge. Within this framework, the present study aimed to examine the academic effects of integrating Anatomage technology into the educational process of medical students. A quantitative design was employed, incorporating pre- and post-intervention assessments, statistical performance analysis, and evaluation of student perceptions. The four-week intervention involved three-dimensional anatomical exploration and collaborative activities focused on morphofunctional correlation. The findings demonstrated improvements in academic performance and increased accuracy in identifying complex spatial relationships. The discussion suggests that systematic use of digital visualization promotes active knowledge construction and deeper conceptual understanding. It is recommended that interactive anatomical technologies be incorporated as a structural complement within health sciences curricula to strengthen competency-based medical education.

Keywords: *digital anatomical simulation, spatial competencies, applied learning*

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English translation of the original article published in Ecuacientífica, Vol. 4, No. 9, pp. 65-74.

ISSN:
3091-1796
Vol. 4 No. 9 PP. 65-74

DOI:
https://doi.org/10.56519/5wxahf27
Mayo 2026

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INTRODUCTION

In recent years, technological transformations have profoundly impacted multiple fields, and education has not been the exception (1). Educational institutions, particularly those centered on the health sciences, face growing challenges to remain aligned with technological advances and satisfy the educational demands of future professionals (2).

Historically, the teaching of anatomy has been based on the dissection of cadavers, physical models and textbooks. During centuries, dissection was considered the gold standard. However, access to cadavers has been restricted for ethical and legal reasons (4,13, 17). In addition, traditional resources usually offer two-dimensional representations that limit spatial comprehension. According to (18), traditional teaching tends to be passive, which reduces student participation and can lead to superficial learning. This has driven the search for more dynamic methods that promote active participation, spatial visualization and practical application of knowledge (19).

The field of the health sciences benefits especially from these innovations owing to the complexity of the content that must be imparted (3). One of the most representative examples is the teaching of anatomy, which is a crucial discipline in the formation of future physicians, since it provides the fundamental knowledge necessary to understand the spatial relations among the organs, tissues and systems of the human body.

Developing the capacity to visualize these structures in three dimensions is essential to develop posterior clinical skills in the medical career. However, achieving this through static means, such as two-dimensional images or limited physical models, can be a challenge (5).

This situation has driven educational institutions to explore alternative methods that can replicate the experience of dissection in virtual or digital formats (6). Another important challenge is the motivation of the students, which often diminishes when they face very abstract content and with high density of information. Anatomy, as a discipline that demands both memorization and comprehension, requires pedagogical strategies that actively involve the students and stimulate their participation during the entire learning process (7).

The integration of interactive technologies in the teaching of anatomy has become an essential tool to overcome the limitations of traditional methods (8). These technologies respond to the growing demand for dynamic and attractive learning environments, and align with the changing needs of medical education upon preparing the students for real clinical practice (9).

Among the most innovative and effective tools are found augmented reality (AR), virtual reality (VR), anatomical simulators and interactive tables. Virtual reality permits the students to enter completely digital environments and explore complex structures from the interior. On its part, augmented reality superimposes digital content on the real environment, permitting visualizing anatomical models through mobile devices or specialized glasses (10).

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Anatomical simulators offer practical experiences that imitate real situations. For example, the simulators of virtual cadavers permit practicing dissections on digital models that reproduce human anatomical variability (11).

Among the most sophisticated tools stands out the interactive Anatomage table. This technology presents three-dimensional anatomical models of high resolution obtained by means of computed tomography (CT) and magnetic resonance (MR). It permits realizing virtual dissections, rotating structures, amplifying specific details and exploring integrated clinical cases (12).

Likewise, the Anatomage table integrates interactive modules that link anatomy with clinical pathology. For example, the students can analyze how a tumor affects surrounding tissues or how a fracture alters muscular insertions, fostering critical thinking and the resolution of problems (14).

The teaching of anatomy is an essential component in the formation of students of health sciences, since it constitutes the base to understand physiology, pathology and clinical practice. From this formative vision augmented reality (AR) represents a highlighted advance in the educational ambit. For example, the applications of AR can project 3D models of organs or complete systems within the classroom, which permits the students to interact with them from distinct angles and in clinically relevant contexts (15).

This technology facilitates a better comprehension of the complex relations among the anatomical structures and their location within the human body, where the interactive Anatomage table has emerged as a highlighted resource that offers an immersive, detailed and adaptable experience to the needs of the student (16).

In change, virtual reality (VR) offers a completely immersive environment that permits interacting with detailed 3D models of anatomical structures. This technology permits that the students practice medical procedures in a safe form and repeat them as many times as necessary until reaching mastery (18).

Diverse studies have evaluated its implementation in different geographic contexts. In the United States they analyzed the incorporation of Anatomage as complement to traditional dissection and found that the students reported greater clarity in three-dimensional comprehension, although they emphasized that the tool results more effective when it is integrated within a structured pedagogical strategy and not as an isolated resource (20).

In this context, the objective of the present study is to analyze the academic effects of integrating Anatomage technology in the formative process of medical students.

MATERIALS AND METHODS

This investigation employed a quantitative and descriptive approach, by means of a pre-experimental design with measurements before and after the intervention. The purpose was to evaluate the impact of the interactive Anatomage table on the learning of anatomy through the implementation of an innovative educational strategy.

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DOI: https://doi.org/10.56519/5wxahf27
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The sample was conformed by 30 students of health sciences enrolled in the subject Morphofunction 1, selected by means of non-probabilistic sampling by convenience. All were taking the subject for the first time and belonged to the same academic cohort, which guaranteed homogeneous learning conditions. An innovative pedagogical strategy was designed integrating the Anatomage table as didactic resource. This tool permitted exploring the human body by means of 3D models, facilitating the comprehension of complex anatomical structures.

Several instruments were utilized to evaluate the impact of the educational strategy. In the first place, knowledge tests (pretest and posttest) composed of 20 multiple-choice questions with unique correct response were applied, oriented to evaluate anatomical identification, spatial relations and morphofunctional correlation.

The instrument was designed by the teaching team of the subject Morphofunction 1, considering the learning outcomes and the programmatic contents established. Subsequently, it was submitted to an internal academic revision by teachers with experience in anatomical teaching, who evaluated the clarity, pertinence and coherence of the items. The observations realized permitted optimizing the drafting and adjusting the level of complexity of some questions, assuring their alignment with the formative objectives of the course.

In order to evaluate the internal reliability of the instrument the Cronbach's Alpha coefficient was calculated from a pilot application realized with students of a previous course, obtaining a value of $\alpha = 0.82$, which indicates an adequate internal consistency for academic ends.

In addition, a satisfaction survey was applied at the end of the intervention, composed of five-point Likert-type items, oriented to evaluate perception of utility, visual clarity, motivation and support to learning. This instrument also was revised by the same experts to guarantee its content validity.

Finally, a structured checklist was employed to register levels of participation, interaction with the tool and performance during the practical sessions.

The results of the pretest and posttest were analyzed by means of t tests for related samples, with the aim of determining if there existed significant differences before and after the intervention. The responses of the satisfaction survey were analyzed in a descriptive form, contributing relevant information on the acceptance and the perception of the technological resource.

The intervention was carried out in three phases. In the first, the pretest was applied to evaluate the initial knowledge. In the second, during four weeks the educational strategy with the Anatomage table was implemented. In the third, the posttest was applied to evaluate the learning outcomes and the satisfaction surveys were collected.

The statistical analysis was realized utilizing the software SPSS. In order to compare the results obtained before and after the intervention the Student's t test for related samples was applied, given that the measurements corresponded to the same group of students evaluated in two distinct moments. This test was selected for treating of continuous quantitative data and for the intra-group character of the design. A level of statistical significance of $p < 0.05$ was established.

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DOI:
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RESULTS

The analysis of results shows a positive impact of the educational strategy based on the use of the interactive Anatomage table on the learning and the levels of student satisfaction.

A t test for related samples was realized to compare the grades before and after the intervention. The mean of the pretest was of 6.5/10, which indicates a moderate comprehension of basic anatomical concepts. In this initial measurement, 7 of the 30 students reached or surpassed the threshold of approval established in 7/10.

In contrast, the mean of the posttest increased to 8.9/10, showing an important improvement of the performance. After the intervention, 27 students surpassed the threshold of approval, which reflects a considerable increment in the proportion of satisfactory performance within the group. The statistical analysis reported a value of $p < 0.05$, which confirms that the difference between pretest and posttest was significant.

Table 2. Results of the Pretest and Posttest

Students	Pretest Score	Posttest Score	Difference
1	7.0	8.9	1.9
2	6.4	10.0	3.6
3	7.1	9.5	2.4
4	8.0	9.6	1.6
5	6.3	9.4	3.1
6	6.3	7.7	1.4
7	8.1	10.0	1.9
8	7.3	8.1	0.8
9	6.0	7.3	1.3
10	7.0	9.6	2.6
11	6.0	9.0	3.0
12	6.0	8.5	2.5
13	6.7	9.0	2.3
14	4.6	6.8	2.2
15	4.8	6.0	1.2
16	5.9	7.7	1.8
17	5.5	7.5	2.0
18	6.8	10.0	3.2
19	5.6	8.3	2.7
20	5.1	6.1	1.0
21	8.0	10.0	2.0
22	6.3	8.4	2.1
23	6.6	8.5	1.9
24	5.1	8.0	2.9
25	6.0	9.2	3.2
26	6.6	9.7	3.1
27	5.3	7.0	1.7
28	6.9	9.1	2.2
29	5.9	8.6	2.7
30	6.2	9.4	3.2

Table 2 evidences a significant improvement in the student performance after the implementation of the new method. The increment of scores oscillated between 0.8 and 3.6 points, which demonstrates variability in the benefits obtained among the participants. These findings suggest that the educational intervention with the interactive Anatomage table was effective to improve the academic performance in the subject Morphofunction 1.

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DOI:
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Results of the satisfaction survey

The results of the satisfaction survey show a high level of acceptance of the new teaching methodology.

Table 3. Summary of results of the satisfaction survey

Evaluated aspect	Percentage of acceptance
Percentage of acceptance	95%
Improvement in the comprehension of anatomical structures	90%
Development of skills of resolution of problems and team work	87%
Connection between theoretical concepts and practical applications	Highlighted by the students

Table 3 indicates in a complementary manner, the students highlighted that the proposal facilitated the articulation between the theoretical contents and their application in practical situations.

The checklist confirmed high levels of participation and commitment during the practical sessions. The students interacted actively with the 3D models, formulated questions and collaborated in an effective manner in group discussions. In addition, the use of clinical cases stimulated critical thinking and facilitated the application of the anatomical knowledge in real scenarios.

DISCUSSION

The findings of this study highlight the significant impact of the use of the interactive Anatomage table as educational strategy in anatomy. The results evidenced a clear improvement in the academic performance, reflected in the substantial increase of the evaluations from the pretest to the posttest (6.5/10 to 8.9/10). This improvement not only shows the effectiveness of the interactive table to facilitate the comprehension of complex anatomical structures, but also coincides with the existing literature, which backs the integration of technology in education to promote active learning.

These results are consistent with the literature that describes the interactive technologies as facilitators of active learning and the retention of knowledge (8,10). Diverse authors have signaled that three-dimensional digital visualization improves spatial comprehension and promotes a more significant construction of knowledge when it is integrated within a structured pedagogical strategy (9,12). In this sense, the Anatomage table not only acts as visual resource, but as didactic mediator that permits repeating virtual dissections, exploring structures from multiple planes and linking anatomical contents with clinical cases (12,14,20), which can explain the increment observed in the academic performance.

The results of satisfaction reinforce the good reception of this innovative methodology. With a 95% of students indicating that the Anatomage table made the learning more attractive and interactive, it is observed that the approach managed to capture the interest of the student body (13). In addition, the 90% reported that the 3D visualizations improved their comprehension, which suggests that the visual supports are especially relevant in subjects that require spatial comprehension.

In addition, the 90% reported that the 3D visualizations improved their comprehension, which suggests that the visual supports are especially relevant in subjects that require spatial comprehension (2).

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CONCLUSIONS

The implementation of the interactive Anatomage table demonstrated to be an effective pedagogical strategy to strengthen anatomical learning in students of health sciences. The obtained results evidenced a significant increment in the academic performance, reflected in the increase of the mean of the posttest with respect to the pretest, as well as in the greater number of students who reached satisfactory levels of performance. These findings confirm that three-dimensional visualization and the digital exploration of the human body favor the comprehension of complex spatial relations and contribute to the development of anatomical competencies essential for medical formation.

Likewise, the integration of interactive technology promoted a more dynamic, participative and student-centered educational experience. The high levels of satisfaction reported evidence that the use of digital anatomical models increased the motivation, the interaction during the practical sessions and the capacity to relate theoretical contents with real clinical applications. The possibility of manipulating anatomical structures, realizing virtual dissections and analyzing clinical cases permitted strengthening active learning and critical thinking within the formative process.

Finally, it is concluded that the incorporation of tools such as Anatomage represents an innovative and complementary alternative to the traditional methods of teaching of anatomy. Its implementation does not intend to replace completely the conventional strategies, but to enrich them by means of technological resources that potentiate the morphofunctional comprehension and the significant construction of knowledge. In this sense, it is recommended that the institutions of higher education integrate progressively digital anatomical technologies within their academic programs, promoting educational models oriented to the development of clinical, spatial and analytic competencies in accordance with the current demands of medical education.

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ISSN:
3091-1796
Vol. 4 No. 9 PP. 65-74

DOI:
https://doi.org/10.56519/5wxahf27
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