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Mobile Application-Supported Instructional Design in Anatomy Education

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Abstract

Vocational anatomy education, particularly in equine science, frequently imposes significant cognitive challenges on students due to the integration of spatially intricate structures with unfamiliar Latin terminology. This study examines the potential of incorporating an interactive three-dimensional mobile application into instruction to facilitate cognitive load management and enhance learning outcomes. The intervention was created by carefully aligning the principles of multimedia learning with the needs of mobile human-computer interaction. Employing an iterative design-based research methodology, a needs analysis involving nine students initially elucidated the primary sources of difficulty. Following these findings, a two-week implementation supported by a mobile application was executed with a distinct sample of eight students and assessed using a mixed-methods design. The quantitative results indicated a significant enhancement from the pre-test to the post-test; the mean score rose from 36.38 to 66.75, with a statistically significant difference ($Z = -2.52$, $p = .008$). Qualitative evidence corroborated these findings, demonstrating that three-dimensional visualizations facilitated understanding, interactive engagement enhanced motivation, and the multisensory learning experience was regarded as beneficial for retention. The results indicate that an instructional design supported by a mobile application, based on cognitive and interaction-focused design principles, can provide a practical, accessible, and scalable approach to enhance learning outcomes in professional anatomy education.

Keywords: Mobile Learning, 3D Visualization, Equine Anatomy, Anatomy Education, Instructional Design.

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1. Introduction

Many people agree that learning clinical anatomy is hard because students have to learn a lot of complicated information and make accurate spatial representations at the same time. In equine studies, this challenge intensifies: students must grasp intricate three-dimensional relationships while navigating an unfamiliar Latin vocabulary [1]. When training primarily utilizes lectures and static two-dimensional materials, learners may encounter increased cognitive load, which can result in diminished motivation, a lower probability of sustained learning, and ultimately impede achievement [1]. This issue goes beyond just "difficult content"; it also has to do with a Human-Computer Interaction (HCI) issue about how information is presented and how to improve cognitive processes during learning. This study examines the efficacy of an educational design that incorporates an interactive three-dimensional mobile application to mitigate cognitive load and improve learning outcomes. The instructional intervention is founded on established principles of human cognition and interaction design. This study aims to clarify the benefits of a mobile-supported strategy in contexts where traditional methods fail to enhance spatial understanding and terminology acquisition.

Richard Mayer's Multimedia Cognitive Theory of Learning [2] mostly guided the design of the lessons. The theory says that people are more likely to learn things that are meaningful when the materials match how the brain processes information, especially when the brain doesn't have to work as hard [3]. It is based on three ideas: the dual-channel assumption (visual and auditory information are processed through separate channels), the limited-capacity assumption (working memory can only hold a certain amount of information at once), and the active-processing assumption (learners actively organize and integrate new information). The mobile app and its integration into the course were designed to put ideas from this framework into action:

- Multimedia Principle: Learners tend to achieve deeper learning from words combined with pictures than from words alone, consistent with the idea of separate channels for verbal and visual processing [5].
- Spatial Contiguity Principle: By placing anatomical labels on or near the relevant structures on the three-dimensional model, the application reduces the cognitive effort needed to map verbal descriptors onto visual information [2]. This design choice is particularly important for building a stable understanding of complex spatial relations in anatomy [4].
- Segmentation Principle: The user-paced and interactive structure lets learners control the flow of information and explore segments at their own pace. This helps keep them from getting too much information at once, which can happen when instructors lead them through complex material all at once [4, 6].

Beyond cognitive alignment, effectiveness in a mobile context depends strongly on usability. The intervention therefore also reflects mobile HCI principles through a systematic integration of cognitive learning considerations with mobile interaction design. The selected application is consistent with common best practices in mobile learning:

- Simplicity and Learnability: Direct manipulation gestures (e.g., pinch-to-zoom, swipe-to-rotate) support an intuitive interface. High learnability reduces the extraneous cognitive load associated with mastering a new tool, helping students allocate attention to anatomical content rather than interface demands [7, 8].
- Splitting Content into Pieces for Microlearning: Mobile learning is most effective when content is presented in short, focused pieces; this approach is often referred to as microlearning [9]. This is consistent with learning theories designed for the mobile era that emphasize context and accessibility [10].

2. Experiments

This study adopted an instructional design-based research methodology as an iterative approach involving the systematic analysis of a practical learning problem, the design of a theory-based intervention, and the implementation and evaluation of that intervention in a real educational context. The research was conducted with second-year students enrolled in the Equestrianism and Coaching program at a state university in Turkey.

The analysis phase of the study includes a comprehensive analysis conducted through surveys and semi-structured interviews with nine students to identify the fundamental pedagogical barriers in equine anatomy education (Appendix A). The findings revealed that students struggled significantly with the high cognitive load resulting from the abstract nature of the anatomical content and the predominantly theoretical nature of the lessons, and that navigating the specialized Latin terminology further complicated this situation. In addition, it was determined that the most important factor hindering learning in equine anatomy education was the lack of visual and interactive materials. In line with these findings, design and development phases were initiated to define the framework of the instructional design. During the process, digital materials developed and selected based on the opinions of subject matter experts were used; the learning process was transformed from a theoretical structure into a visual and interactive learning experience. After completing the development phase, the implementation phase was initiated to examine its effectiveness in reducing the identified learning difficulties. The instructional design was planned for a two-week implementation process with a new sample group (N=8) consisting of eight participants aiming to achieve cognitive and affective goals. Information regarding the instructional implementation process related to the application phase is presented in Table 1.

Week (Class Hours)	*Main Focus/Topics*	*Methods*	*Assessment*
Week 1 (3 Hours)	Head and Forebody Bones: Skull, cervical vertebrae, spine, and forelimb bones. Cognitive Domain: Knowledge, Comprehension, Application (Demonstration on horseback), Analysis (Evaluating problems). Affective Domain: Response, Appreciation.	Lecture, Mobile Application Demonstration, Question-Answer, Demonstration and Practice.	Pre-test application. Question-and-answer session after the content.
Week 2 (3 Hours)	Hindquarters and Evaluation: Hind leg bones, separating front and hind leg bones. Cognitive Domain: Synthesis (Organizing), Evaluation (Predicting and discussing health issues).	Straightforward Presentation (Presentation) and active repetition with the Mobile Application, Q&A.	Reinforcement with Q&A after the mobile application.
Week 3 (3 Hours)	General Evaluation	Measurement and Evaluation	Final Test Application. Presentation of the differences between the pre-test and final test.

Table 1. Weekly Plan of the Instructional Design for the Implementation Process

A mixed-methods approach was used in the evaluation process. To determine the quantitative change in anatomy-related gains, a pre-test–post-test design was applied using paper-based tests based on the same learning outcomes (Appendix B). After the intervention, semi-structured interviews were conducted with four volunteer participants to obtain qualitative feedback on the learning experience. Written informed consent was obtained from all participants in the study prior to data collection. Quantitative data were analyzed using the Wilcoxon signed-rank test for dependent measurements, while qualitative data were analyzed using thematic analysis based on the transcription of interview recordings.

3. Results and discussion

The findings of the needs analysis showed that students experienced difficulties in learning the positions, names, and functions of bones, particularly in the anatomy of the horse course. Participants and literature experts stated that this difficulty was mainly due to two reasons: (i) the foreign/Latin origin of concepts in anatomical terminology and (ii) the course being mostly theory-based. In this context, the goal was to implement a teaching design process that appeals more to the senses of students in order to reduce learning difficulties.

Similarly, during the analysis phase of the teaching design process, it was determined that students' difficulties in learning anatomy content were related to the theoretical intensity of the topics and the Latin origin of the concepts. Student opinions regarding the teaching design supported by the mobile application developed in line with these findings are presented below:

- "...this course, taught over three weeks, was more application-oriented than the regular horse anatomy course. This made it more memorable and appealing due to the presentation of more visual content... (Participant-1)" (Keywords: Visuality, attention, memorability)
- ”...I think this course was effective and memorable because the visually-focused course appealed to more senses and I felt I could learn better with my visual memory. People now believe that visual learning is more effective and that new content and materials should be used in education with the advancement of technology. I believe that such a course should continue to be offered to students in the future...(Participant-2)" (Keywords: Visual, effective, visual memory, visual-auditory-focused education)
- "...this application made learning new things easier, and presenting the content with visuals made the course fun. Also, seeing the location of the bones in 3D in the application, which I previously couldn't understand or had difficulty understanding, increased the course's permanence and effectiveness in my opinion. I think that if anatomy lessons are taught like this in the future, success will also increase (Participant-3).” (Keywords: Visual, fun, success, retention, 3D material).
- “...seeing which bone is where and how it is positioned in 3D instantly increases retention and success. I think such an application will increase success in future lessons (Participant-4)” (Keywords: 3D, retention, success)

According to interviews with participants, students generally stated that the training:
supported retention,

- Positively affected success,
- Facilitated learning,
- Should be conducted with a similar approach in future lessons,
- That visuals and 3D materials positively affected learning.
- Based on these findings, mobile application-supported instructional design indicates a significant improvement in student learning outcomes.

In line with these findings, mobile application-supported instructional design indicates a significant improvement in student learning outcomes. The quantitative and qualitative findings obtained are summarized below:

- Quantitative Findings: The results obtained from the anatomy proficiency test are presented in Table 2.

Measurement	*n*	*Median*	*Mean*	*SD*	*Z*	*p*
Pre-test	9	36.0	36.38	22.99		
Post-test	9	77.5	66.75	30.49	-2.52	.008

Table 2. Wilcoxon Signed-Rank Test Results for Pre-Test and Post-Test Anatomy Knowledge Scores

According to the results of the Wilcoxon Signed-Rank Test for the Pre-Test and Post-Test Anatomy Knowledge Scores presented in Table 2, the mean score increased from 36.38 (SD = 22.99) in the pre-test to 66.75 (SD = 30.49) in the post-test. The nonparametric Wilcoxon signed-rank test, used for dependent samples, indicates that this increase is statistically significant ($Z = -2.52$, $p = .008$). This finding demonstrates a significant increase in student academic achievement.

- Qualitative Findings: Thematic analysis of student interviews corroborated the quantitative findings and offered elucidative insights into the learning experience. The main themes that emerged are as shown in Figure 1:

Figure 1. Themes and Categories Related to Mobile Learning–Supported Equine Anatomy Education

  - Better Visualization and Understanding: Students said that interactive 3D models helped them understand abstract anatomical ideas better. One person said, "Seeing where the bones are in 3D in the app made the lesson more memorable and useful."
  - Increased Interaction and Motivation: The lesson was seen as more "interesting" and "fun" than regular lectures because it was interactive and visual. People said this made them pay more attention and want to learn more.
  - Strengthening the Retention of Learning: Students said that the app's multisensory experience helped them remember what they learned for longer. One student said, "I think this class is effective and long-lasting because it appeals to more senses, and I think I can learn better with my visual memory."

The results suggest that an instructional design based on cognitive and interaction principles can resolve ongoing challenges in anatomy education. The significant improvement in test results can be attributed to the incorporation of technology and the specific strategies employed by the mobile application to facilitate active knowledge generation, as predicted by the Multimedia Cognitive Learning Theory [2]. A vital component of this accomplishment is the concentrated emphasis on managing cognitive stress [6]. Qualitative research strongly supports this viewpoint, since students clearly link 3D representations and engagement to improved understanding and retention.

The restricted sample size (N=8) presents a fundamental challenge in this study, as it hinders the extrapolation of the results to other contexts. Additional research is necessary with larger and more diverse student groups across other educational institutions to corroborate these findings. This study does not include a comprehensive usability evaluation of the mobile application. Future research should incorporate established IBE methodologies, such as the System Usability Scale (SUS) [11] or heuristic evaluation [12], to quantitatively analyze user experience and its relationship with learning outcomes. Comparative studies are essential for assessing the relative efficacy and cost-benefit analysis of this mobile application-based method in anatomy education compared to other emerging technologies, such as Augmented Reality (AR) and Virtual Reality (VR).

Recent systematic reviews and meta-analyses demonstrate that immersive technologies, including augmented reality and virtual reality, can substantially improve anatomy education. These tools make learning captivating and invigorating. However, they typically require specialized hardware, significant development costs, and technical support, which may hinder their widespread adoption, particularly in professional or resource-constrained settings. This research significantly advances this domain. It shows that a well-designed, cognitively informed, and very easy-to-use mobile app can help students learn a lot more by letting them work on their own devices. This shows a model of technology integration that is useful, can be used by many people, and will last over time. It could have a big effect on education.

4. Conclusion

This research illustrates that an instructional design augmented by a mobile application, grounded in the principles of multimedia learning and mobile interaction, can markedly enhance student achievement, engagement, and knowledge retention in a demanding professional anatomy course. The intervention effectively diminished cognitive barriers to learning by converting abstract, text-laden material into a tangible, interactive, and multisensory experience. The fundamental contribution of this study to the field of IBE in education is that it provides important evidence for a sustainable and scalable technology integration model. By presenting a validated case study of how the application of fundamental cognitive and IBE principles can solve persistent pedagogical problems, it provides practical instructional design for user-centered instructional design in specialized fields.

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Authors' Declaration

Conflicts of Interest: The authors declare that they have no conflicts of interest related to this study.
Use of language tools: DeepL was used to support translation and language polishing of parts of the manuscript. No tool was used to generate research data or to make scientific decisions. The authors reviewed and verified the accuracy of the translated text and take full responsibility for the final manuscript.

Authors' Contribution Statement

The authors contributed jointly to the conceptualization and research design, preparation of data collection tools, implementation of the application, analysis of data, and writing of the article. The final version of the article has been reviewed and approved by all authors.

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Appendix

A.

Attitude Scale Towards Anatomy Lessons

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I feel upset if I miss even a single hour of the Anatomy course.					
I would have taken the Anatomy course even if it were offered as an elective.					
The topics covered in the Anatomy course are interesting to me.					
I would be pleased if attendance were not compulsory in the Anatomy course.					
I would like to teach Anatomy in the future.					
The Anatomy course is enjoyable.					
Despite all its difficulties, I am satisfied that I have taken the Anatomy course.					
I genuinely like Anatomy.					
I feel comfortable during the Anatomy course.					
I actively participate in the Anatomy course.					
I feel sleepy during the Anatomy course.					
I feel bored while studying for the Anatomy course.					
I feel disgusted by the materials used in the course.					
I am afraid of the skeletons used in the course.					
Being assessed by the instructor on what I have learned motivates me.					
Repeating a topic in front of my classmates during the Anatomy course discourages me from that topic.					

I have positive feelings toward Anatomy.					
The instructor's approach in teaching Anatomy affects my academic performance.					
What I hear about the Anatomy course from senior students before taking it affects my attitude toward the course.					
The teaching method applied in the Anatomy course affects my academic performance.					
Hearing from friends studying at other faculties or universities that Anatomy is a difficult course causes me to lose interest in it.					
I do not think I will be able to use the knowledge I learn in Anatomy again in the future.					
I believe that the number of hours allocated to the Anatomy course should be increased.					
The fact that the knowledge learned in the Anatomy course is related to current topics makes me more willing to study.					

Student Opinion Scale Regarding the Use of Technology in Anatomy Education

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It contributes to understanding experiments that cannot be conducted in the laboratory.					
The use of technology enriches the learning environment.					
The use of technology enhances my imagination.					
It helps improve my creative thinking skills.					
It increases my interest in learning the topics.					
It motivates (encourages) me to learn more.					
The use of technology improves my teamwork skills.					
It contributes to the development of my scientific thinking skills.					
It increases opportunities for participation in learning activities.					
I would like technology to be used more frequently in courses.					

The Contribution of Technology to Learning and Access to Information

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It helps me understand the content of the topic easily.					
It has a positive effect on my ability to learn topics in a short time.					
It provides various opportunities for me to access information quickly.					
It appeals to multiple senses.					
It helps me understand the content of the topic easily.					
It has a positive effect on my ability to learn topics in a short time.					
It provides various opportunities for me to access information quickly.					
It appeals to multiple senses.					

B.

Name and Surname:
Department / Class:

Evaluation Questions

1. How many digits does a horse have, and what is the name (or names) of this digit/digits?

2. Classify the following bones as skull bones, cervical vertebrae, other vertebrae, hind limbs, and forelimbs.

– Maxilla, atlas, mandible, axis, scapula, humerus, femur, radius, fibula, patella, ulna, fibula, thoracic vertebrae, tibia, sacral vertebrae, lumbar vertebrae, phalanx

3. What is the distinguishing feature that differentiates the atlas and axis vertebrae from the other cervical vertebrae?

4. Explain the anatomical region in which the maxilla and mandible bones are located and describe their functions.

5. Explain the differences between the atlas and axis vertebrae.

6. Place the following bones correctly on the skeletal model.

– Maxilla, Atlas, Mandible, Axis, Scapula, Humerus, Femur, Radius, Fibula, Patella, Ulna, Fibula, Thoracic Vertebrae, Tibia, Sacral Vertebrae, Lumbar Vertebrae, Phalanx

7. If a horse shows discomfort in its forelimbs, which of the following bones could be suspected as the source of the problem? Mark the appropriate option(s).

– Scapula, Humerus, Femur, Radius, Fibula, Patella, Ulna, Fibula, Thoracic Vertebrae, Tibia, Phalanx

8. If a horse shows discomfort in its hind limbs, which of the following bones could be suspected as the source of the problem? Mark the appropriate option(s).

– Scapula, Humerus, Femur, Radius, Fibula, Patella, Ulna, Fibula, Thoracic Vertebrae, Tibia, Phalanx

9. If you were required to evaluate a horse's health condition from an anatomical perspective, would you be willing to participate in a discussion in such a setting?
If you did participate, how would you respond to someone who claims that the maxilla bone is related to limb diseases, and how would you scientifically demonstrate that this claim is incorrect? Explain your reasoning.