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Development of An Augmented Reality-Based Anatomy Module To Improve Student Learning Outcomes

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Abstract

The teaching of anatomy at university level still faces serious challenges, particularly in terms of spatial visualisation, the limitations of conventional teaching materials, and low student motivation. In the Physical Education, Health, and Recreation (PJKR) programme at Hamzanwadi University, this situation is evident in the low motivation to study anatomy, the predominant use of two-dimensional textbooks that are difficult to understand, and the lack of innovative learning modules. This situation has resulted in students having a poor understanding of the structure of the body, the musculoskeletal system, and the relationship between anatomy and the functions of movement in sport. This study aims to develop an anatomy learning module using the VisioBody Augmented Reality (AR) platform and to assess its validity, practicality and effectiveness in improving students' learning outcomes. This study employs a Research and Development (R&D) approach using the ADDIE model, which comprises the stages of analysis, design, development, implementation and evaluation. The study involved 70 Physical Education and Health Education students at Hamzanwadi University, who were divided into an experimental group and a control group using a post-test-only control group design. The instruments used included expert validation sheets, practicality questionnaires and learning outcome tests. The validity of the product was assessed using the content validity ratio (CVR) and content validity index (CVI), whilst its effectiveness was analysed through statistical tests of student learning outcomes. The research findings indicate that the VisioBody AR-assisted anatomy module is highly valid and practical for use in teaching. The effectiveness test revealed a significant difference between the experimental group and the control group, with a significance level of $p = 0.000$. The average learning outcome for the experimental group was 76.59, which was higher than that of the control group at 68.08. These findings demonstrate that the VisioBody AR module is effective as a virtual laboratory that helps reduce cognitive load, reinforces the relationship between anatomical structures and motor function, and promotes students' independent learning and digital literacy. Consequently, AR-based anatomy modules are well-suited for use as an innovation in anatomy teaching at universities.

Keywords: Learning module, anatomy, Augmented Reality (AR), learning outcomes, Physical Education, Health Education students

1. INTRODUCTION

The teaching of anatomy at university level requires serious attention, as these subject forms the basis for understanding the structure of the body, the relationships between its parts, and the functions of human movement. Anatomy is not a simple subject. Nokovitch et al., (2025) identify visual-spatial ability as a key predictor of learning time, performance, and mastery of anatomical knowledge. This makes anatomy a complex, abstract subject that requires a high degree of visualisation. Success in learning anatomy does not rely solely on memorising terms, but also on the ability to construct accurate spatial representations. The complexity of the anatomical material has a direct impact on students' learning experience. Students often struggle to understand the structure of the body, the location of organs, the musculoskeletal system, and the relationships between different parts of the body, as the subject of anatomy requires three-dimensional spatial understanding. Chytas et al., (2021); Yammine & Violato, (2015) state that the teaching of anatomy should focus on three-dimensional spatial understanding, rather than merely on achieving good results in general knowledge tests. (García-Robles et al., (2024) also report that immersive technology is superior to textbooks, atlases and didactic lectures in the teaching of anatomy. Students' difficulties stem not only from the breadth of the material, but also from the limitations of how the material is presented during the learning process.This problem is becoming increasingly apparent because the teaching of anatomy in higher education still relies heavily on textbooks, two-dimensional images, atlases and verbal explanations that lack interactivity. Çeken & Taskin, (2022); Mayer, (2024) explains that effective multimedia learning requires the purposeful integration of text and visuals so that learners can choose, Department of Education, Faculty of Graduate Studies, Ganesha University of Education, Indonesia organising and linking information in the most effective way. Cavanagh & Kiersch, (2022) reinforce this view through the application of CTML in multimedia learning design. On the other hand, Skulmowski & Xu, (2021) explain that learning difficulties arise when extraneous cognitive load is too high, particularly when learners have to integrate various separate sources of information themselves. In an anatomical context, the prevalence of static media and verbal explanations makes it difficult for students to construct a comprehensive mental model.Given these circumstances, the main issues in anatomy teaching encompass four areas. Firstly, students' conceptual understanding is poor because teaching often stops at the identification of parts and terminology, without progressing to an understanding of structural relationships, orientation and function. Secondly, student engagement is low because the use of static media limits active exploration and student-centred learning experiences. Thirdly, the currently available media or modules do not yet support concrete anatomical visualisation, even though this subject matter requires three-dimensional representations that can be viewed from various angles. Fourthly, there are currently no AR-based anatomy modules available that have been systematically designed to meet students' needs.

In such situations, the use of Augmented Reality (AR) becomes particularly relevant. AR presents anatomical objects in three-dimensional form, integrated with the real-world environment, enabling students to observe bodily structures in a more concrete, dynamic and contextual manner. Aldeeb et al., (2024) summarise the benefits of AR in enhancing spatial understanding, mental rotation, attention, motivation, self-confidence and learning satisfaction. Williams et al., (2024) also review the development of AR as an educational tool that presents digital anatomical models via mobile devices or *head-mounted displays*. AR is not merely a technological innovation, but a learning medium well-suited to the nature of anatomical material.From a pedagogical perspective, AR offers added value as anatomical structures can be observed in greater detail and in an interactive manner. Students can study the shape, position and relationships between structures through a learning experience that more closely mirrors real-world conditions. AR also provides a stronger visual context than two-dimensional images, making it easier for students to understand structures that are difficult to observe directly. This is important in the study of anatomy, particularly when covering the musculoskeletal system, the location of organs, and the spatial relationships between body parts.

Nevertheless, international research findings highlight a key issue: AR does not always lead to improved learning outcomes unless accompanied by effective instructional design. Salimi et al., (2024) reported greater improvements in anatomical knowledge through XR technology compared to traditional approaches, particularly when used as a supplementary learning resource. Bölek et al., (2021) still found varying results regarding the impact of AR on anatomical learning outcomes. Williams et al., (2024) It also notes methodological limitations, the diversity of interventions, and inconsistencies in terminology across many studies. This means that the crux of the matter lies not in the use of AR alone, but in how AR is integrated into learning.Based on the above, it can be concluded that research into the development of Augmented Reality-based anatomy modules to enhance student learning outcomes is essential, as it addresses the real-world needs of anatomy teaching in higher education. Anatomy is a complex and abstract subject that requires a high degree of visualisation; students often struggle to understand the structure of the body and the relationships between its parts; yet teaching still relies heavily on static materials and verbal explanations. On the other hand, recent studies suggest that AR offers benefits in terms of visualisation, motivation and the quality of the learning experience, but these benefits are more pronounced when supported by a systematic approach to the design of teaching materials. From this review of the literature, it can be concluded that a significant research gap lies in the development of anatomy modules that not only utilise AR as a technological feature, but also integrate it into teaching materials that are structured, self-directed, interactive, and designed to enhance student learning outcomes. Therefore, this article aims to demonstrate that the development of AR-based anatomy modules is a pedagogical solution that is logical, theoretically sound and relevant to the challenges of contemporary anatomy teaching.

In the context of students at Hamzanwadi University, the need for AR-based anatomy modules is becoming increasingly important. Students require teaching materials that not only present information but also help build conceptual, visual-spatial, and functional understanding in an integrated manner. Therefore, the development of AR-based anatomy modules is worthy of being a research focus as it is relevant to the nature of anatomy material, aligns with the demands for innovation in higher education, and has the potential to improve student learning outcomes more effectively.This situation highlights a clear gap in the research. Firstly, whilst there is already a significant body of research on AR in education including in the field of anatomy the focus remains predominantly on applications, devices, holograms or comparisons of media; there has been little attention paid to the development of systematically structured anatomy modules as teaching materials. Boyanovsky et al., (2024), for example, propose a methodology for developing and delivering AR-based anatomy laboratory sessions using a systematic sequence of holograms; however, their focus lies on the design of laboratory courses rather than on anatomy modules that students can use as structured self-study materialsSecondly, research on anatomy learning modules already exists, particularly in the form of *online educational modules* and blended learning. Bandekar et al., (2025) reported that online modules on musculoskeletal anatomy make extensive use of videos, 3D models and virtual laboratories, and support visualisation and retention; however, that study did not specifically address the integration of anatomy modules with AR. Thirdly, research specifically examining the impact of AR-based anatomy modules on student learning outcomes remains limited. This limitation is evident from the reviews by Bölek et al., 2021); Williams et al., (2024) all of which highlight the need for research that is more rigorous, more focused in terms of instructional design, and clearer in assessing learning outcomes.

For this reason, the context of students at Hamzanwadi University is significant as a setting for research implementation. The development of AR-based anatomy modules in this context is relevant because students require teaching materials that not only present anatomical content, but also structure the learning sequence, provide guidance for exploration, and offer interactive three-dimensional visualisations. Thus, the focus of the research does not stop at the use of AR technology, but rather on the development of an anatomy module capable of integrating content, learning activities, visual media and assessment in a pedagogically sound manner. This direction aligns with the recommendations of Asoodar et al., (2024) regarding the importance of theoretical foundations in AR/VR/MR design, as well as with the framework proposed by Wood et al., (2025) which links digital anatomy to reduced cognitive load, motivation, *feedback*, and active learning.

In light of these gaps, the objectives of this study are fourfold. Firstly, to develop an AR-based anatomy module tailored to the nature of the anatomy material and the learning needs of students at Hamzanwadi University. Secondly, to assess the suitability of the module in terms of content, media and instructional design. Thirdly, to evaluate the practicality of the module in real-world use by students. Fourthly, to analyse the effectiveness of the module in improving student learning outcomes. Setting this objective is important because the current literature has not yet extensively combined these four dimensions within a single comprehensive research design, particularly in the case of AR-based anatomy teaching materials that are focused on learning outcomes. The novelty of this study lies in three aspects. Firstly, this study focuses on the development of an anatomy module integrated with AR technology, rather than merely using an AR application as a temporary teaching aid in the classroom. Secondly, this study combines printed and digital teaching materials with interactive 3D visualisations, thereby providing students with a learning experience that is both more structured and more concrete. Thirdly, this study aims to improve student learning outcomes within the context of Hamzanwadi University, thereby making a more specific empirical contribution to the implementation of AR-based anatomy modules in higher education. From an academic perspective, this novelty bridges the gap between AR studies which tend to focus on devices and module studies, which generally have not yet been integrated with AR.

2. THEORETICAL FRAMEWORK

2.1. Learning Module Concept. A learning module is understood as a systematically organised learning package designed to help learners achieve their learning objectives in a step-by-step and self-directed manner. Within the tradition of modular teaching materials, Wahidah et al., (2019) defines a module as material that must clearly provide guidance on learning, practice, feedback and assessment. The key characteristics of a good module include *self-instructional*, *self-contained*, *stand-alone*, adaptive, and user-friendly. These characteristics are important because modules not only contain content, but also structure the students' learning experience from the orientation stage through to mastery of the subject matter. In the context of higher education, this principle aligns with Charokar & Dulloo, (2022) concept of *self-directed learning*, which views students as adult learners who need to manage their own learning objectives, strategies and assessment. Studies by Lu et al., (2023) on *self-directed learning* modules for medical students and Aulakh et al., (2025) on *self-directed learning modules* in histology demonstrate that well-designed modules can enhance learning autonomy, aid mastery of the subject matter, and improve academic performance, particularly when combined with blended learning. From a constructivist perspective, an effective module is not merely a medium for conveying information, but a means of constructing knowledge through guided activities. Zhiqing, (2015) viewed learning as an active process of construction through assimilation and accommodation, whilst Puntambekar, (2022) emphasised social support, context, and *scaffolding*. In anatomy education, Bergman et al., (2013) associate constructivism with learning that is constructive, collaborative, contextual, and self-directed. Therefore, AR-based anatomy modules need to be designed not only to be informative but also to provide scope for exploration, practice, and active student engagement.

2.2. Anatomy Lessons. Anatomy is the field that studies the structure of the body, the relationships between its parts, and how these relate to function. The subject matter is highly visual, spatial and hierarchical. Students must not only recognise the terms or names of structures, but also understand the location, orientation, depth, relationships and functions of the body's components. Therefore, the study of anatomy requires strong visual representations. Nokovitch et al., (2025) reported that visual-spatial ability is closely linked to learning time, performance, and mastery of anatomical knowledge. Taylor et al., (2021); Williams et al., (2024) also noted that anatomical material is often more difficult to learn when instruction relies on non-immersive and short-duration resources.

The challenges students face when learning anatomy arise in three main areas. Firstly, the subject of anatomy requires three-dimensional understanding, whereas the predominant learning resources are still texts, atlases and two-dimensional images. Secondly, students often struggle to fully grasp the relationship between structure and function without the aid of visual aids that can be viewed from various angles. Thirdly, limitations in terms of time, facilities and teaching approaches can diminish the depth of the learning experience. Reviews Hackett & Proctor, (2016); Moro et al., (2017) show that digital technologies, particularly AR and VR, are increasingly being used to address these limitations as they can present anatomical structures in a more concrete and interactive manner. Consequently, visual and interactive media are not merely supplementary but are a core requirement in modern anatomy teaching.

2.3. Augmented Reality (AR) Augmented Reality falls within the spectrum of *mixed reality*, which Milgram & Drascic, (2021) Milgram and Kishino (1994) described as the range between the real environment and the virtual environment. Azuma, (2021) defined AR as the interactive, real-time integration of three-dimensional virtual objects into the real environment. In education, AR has three key features: 3D visualisation, interactivity, and integration with real-world contexts. These three features make AR highly relevant to the study of anatomy, as abstract objects can be displayed in a form that can be rotated, zoomed in on, and observed directly from various angles. In theory, the advantages of AR can be explained by *dual coding theory*, *cognitive load theory*, and *the cognitive theory of multimedia learning*. Paivio, (2021) explains that visual and verbal information processed together enhances comprehension and retention. Sweller, (2020) explain that effective instructional design should minimise unnecessary cognitive load. Lai et al., (2019) identifies learning through words and images as the core of effective multimedia. In the context of anatomy, AR is relevant because it combines text, labels and 3D objects within a single learning experience. International evidence also points in this direction. Tang et al., (2020) reported the rapid growth of AR in medical education. Bork et al., (2021) identified the potential of collaborative AR in *gross anatomy*. Mendez-Lopez et al., (2022) found that students had a positive preference for AR-based neuroanatomy learning. K. A. Bölek et al., (2022) reported an increase in motivation for learning neuroanatomy. García-Robles et al., (2024) found that XR outperforms textbooks, atlases, and didactic lectures in terms of anatomical knowledge. However, Salimi et al., (2024; Williams et al., (2024) point out that results vary considerably, meaning that the effectiveness of AR is largely determined by the quality of its instructional design.

2.4. Learning Outcomes.Learning outcomes refer to changes in students' abilities following the learning process Swadesi, I. K. I., & Kanca, I. N. (2020). In this article, learning outcomes focus primarily on the cognitive domain. Agarwal, (2019) Revised Bloom's Taxonomy provides a robust framework for measuring these dimensions, ranging from recall, understanding, application, analysis and evaluation to creation. Pappas et al., (2023) state that this taxonomy helps lecturers align learning objectives, learning activities and assessment. In anatomy teaching, the most commonly assessed indicators are conceptual mastery, understanding of structural relationships, identification skills, and the application of knowledge to case studies or bodily movements.

There is no single factor influencing student learning outcomes in the context of AR-based anatomy. Visual-spatial ability, motivation, independent learning, media quality and instructional design all play a role. Nokovitch et al., (2025) link learning outcomes in anatomy to spatial ability. Knowles regards learning autonomy as the foundation of adult learning, and Aulakh et al., (2025) found that *self-directed learning* can enhance the cognitive performance of medical students. On the other hand, *cognitive load theory* and CTML explain that learning outcomes improve when material is presented with a clear, concise visual-verbal structure that does not overload working memory. Consequently, it is logical to measure the students' learning outcomes in this study through improvements in cognitive achievement following the use of an AR-based anatomy module that is systematic, visual, interactive and user-friendly.

3. RESEARCH METHODOLOGY

This study employs a Research and Development (R&D) approach, as its objective is to produce an educational product in the form of an Augmented Reality (AR)-based anatomy module, whilst also testing its quality and effectiveness. The R&D framework draws on Gall et al., (1996), who view the development of educational products as a systematic process involving design, validation, revision and field testing. In its implementation, this study utilised the ADDIE model proposed by (Branch & Varank, (2009), which comprises five stages: analysis, design, development, implementation and evaluation. This model was chosen because it is simple, systematic and suitable for the development of digital teaching materials. The theoretical basis of the research comprises six main references, namely (Branch & Varank, 2009; Gall et al., 1996; R. E. Mayer, 2002; Sweller, 2011; Wheeler, 2004). These five theories provide the basis for product design, self-directed learning, cognitive load management, and the measurement of cognitive learning outcomes.

The research subjects comprised subject matter experts, media experts, lecturers teaching the anatomy course, and students as product users. The subject matter experts were tasked with assessing the module content's alignment with anatomical concepts, the depth of the material, the accuracy of terminology, and its relevance to the learning outcomes. Media experts assess the presentation, readability, navigation, visual design, and integration of AR features. The product users are students of the Physical Education, Health, and Recreation (PJKR) programme, Faculty, Hamzanwadi University. In the article, the number of subjects is specified in detail, for example subject matter experts, media experts, students in the pilot study, and students in the field study. The selection of students as subjects is based on Canaran, (2025) theory of self-directed learning, as students, being adult learners, require teaching materials that are structured, self-directed and user-friendly. Meanwhile, the measurement of learning outcomes refers to the revised Bloom's taxonomy by Anderson & Krathwohl (2001) Anderson and Krathwohl (2001), particularly in the cognitive domain.

The analysis phase was carried out to identify learning needs, student characteristics and the scope of the anatomy syllabus. Data was collected through interviews with lecturers, student questionnaires and a review of the curriculum and course syllabus. This analysis covers students' learning difficulties, visual-spatial needs, readiness to use devices, and the learning objectives to be achieved. The design phase includes creating structure modules, formulating learning objectives, pet material, designing visuals, designing marker AR, storyboard visualization 3D, and creating research instruments. At this stage, the module design draws on R. E. Mayer, (2002) to ensure that text, images and 3D objects complement one another, and on Sweller, (2011) to ensure that the presentation of the material does not overburden students' working memory.

The development phase involves creating anatomical modules, producing illustrations, developing 3D objects, integrating them with the AR application, and designing assessment questions. The initial product is then validated by subject matter experts and media specialists. Feedback from the validators is used to revise the content, language, visual design and AR functionality. The implementation phase was carried out through limited trials and field tests. In the limited trials, the module was used by a small number of students to assess the readability, ease of use and stability of the AR features. Following revisions, the product was rolled out to a wider group. Students took a pre-test, used the module in their learning, and then took a post-test. The evaluation phase was conducted formatively at each stage and summatively at the end of implementation to assess the validity, practicality, and effectiveness of the product.

The research instruments include subject matter expert validation sheets, media expert validation sheets, student response questionnaires, pre-test and post-test learning outcome tests, and observation sheets. The subject matter expert validation sheet is used to assess the accuracy of concepts, breadth of content, structure, and language. The media expert validation sheet is used to assess visual design, navigation, AR integration, and ease of access. The student feedback questionnaire is used to assess the practicality of the module, the appeal of the interface, the clarity of instructions, and the benefits of the product. The learning outcome assessments were designed based on Anderson & Krathwohl, (2001) cognitive indicators, specifically at the levels of recall, comprehension, application and analysis. Observations were used to record student engagement and technical difficulties during the learning process. Data were collected through interviews, questionnaires, documentation and learning outcome assessments.

Data analysis comprises descriptive analysis and quantitative analysis. Descriptive analysis is used to assess validity, practicality and user response through percentage scores, which are then interpreted into the categories of highly valid, valid, moderately valid, less valid, or highly practical, practical, moderately practical, and less practical. The interview and observation data were analysed using descriptive qualitative methods. Quantitative analysis was used to assess the effectiveness of the module through pre-test and post-test scores, N-gain calculations, and a paired-sample t-test to test the significance of the improvement in learning outcomes. A module is deemed effective if the post-test score is higher than the pre-test score, the N-gain score falls into the moderate or high category, and the results of the t-test are significant. With this design, the resulting product is expected to meet three key criteria: validity, practicality and effectiveness.

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4. RESULT

4.1. Product Development Results. The product developed in this study is an anatomy learning module supported by the VisioBody Augmented Reality (AR) application, comprising a printed module, a user guide, and an Android-based AR application. During the development phase, the product was created through five main activities: the production of the module and guide, the development of the VisioBody AR application, the integration of the module with the application, expert validation, and product revision. In its final form, the teaching module is systematically organised into three sections: the introductory section, the main section, and the concluding section. The introductory section comprises the cover page, foreword, table of contents, instructions for use, and concept map. The main section contains the introduction, modules one to five, a summary, a glossary, a learning outcomes rubric, and a flowchart assessment and references. The final section contains the conclusion, answer keys for the formative assessments, a biography of the writing team, as well as the back cover and synopsis. During the revision stage, a user guide was also incorporated into the module to make it more practical for students to use.

The content included in this product focuses on the anatomy of the human body's posture and musculoskeletal system. The content has been developed in accordance with the CPL and RPS for the anatomy course at Hamzanwadi University, and is structured from basic concepts to more complex ones. Substantively, the material covers five main topics: the anatomy of body planes and directions of movement; the anatomy of the upper passive musculoskeletal system; the anatomy of the lower passive musculoskeletal system; the anatomy of the upper active musculoskeletal system; and the anatomy of the lower active musculoskeletal system. In addition to presenting the concepts, the product also includes summaries, a glossary, formative assessment questions, assessment rubrics, and explanations of the relationship between anatomical structures and motor functions. In subsequent developments, the app's content has also been enhanced with information labels for 3D objects, anatomical terms aligned with *Nomina Anatomica*, and animated videos linking anatomical structures to examples of movement.

The AR features available in the VisioBody app are designed to support three-dimensional visualisation, interactivity and ease of use. The app features a splash screen, a main menu, an AR camera for marker scanning, a 3D object interaction view, and an interactive quiz menu. The AR assets developed include 3D models of the human body, upper and lower muscles, upper and lower bones and joints, five AR markers, motion direction videos/animations, a quiz question bank, as well as interface icons and graphics. In the updated version, the app features a content exploration menu, motion guidance videos, motion analysis buttons for passive and active movement exercises, a muscle contraction mechanism button, and quizzes that display the final score immediately. Students use the module in stages: first, they read the introductory material in the module; then they scan the provided markers using the VisioBody app on their smartphone; they view the 3D anatomical models and interactive features that appear; and finally, they consolidate their understanding through learning activities and practice questions. This approach means that the module serves not only as reading material, but also as a self-directed learning tool integrated with a virtual laboratory.

Table 1: Validation results

Type of assessment	Number of Experts	CVR rate	CVI value	Category	Interpretation of Results
Media expert	6	0,82	0, 93	Valid	The media aspects are deemed suitable for use. The product has met the requirements for validity in terms of presentation, visualisation and AR media support, although it still requires technical and design refinements.
Subject expert	6	1,00	1,00	valid	The content of the material was assessed as being very strong. The anatomy material was deemed to be appropriate to the curriculum requirements, the characteristics of the students and the learning objectives.
Average across all aspects of product validation	6	0,94	0,98		Overall, the VisioBody AR-assisted anatomy module has been found to be highly valid

4.2. Practicality Test Results. The usability testing with students was conducted in two stages: a small-group pilot study and a large-group usability test. In the small-group pilot study, the module was tested on 15 Physical Education and Health Education students at Hamzanwadi University to gain an initial understanding of the comprehensibility of the content, the clarity of the instructions, the layout, and the ease of use of the AR-assisted VisioBody module. The results showed an average score of 92.4, falling into the 'very practical' category. Of the 15 students, two rated it as 'practical' with scores ranging from 80 to 89, whilst the remaining 13 rated it as 'very practical' with scores ranging from 90 to 100. Data This shows that, since the pilot study, the module has been well received by students as a teaching aid for anatomy.

During the large-scale practicality testing phase, the module was tested on 25 students. The results showed an average practicality score of 83.6, which remained in the 'very practical' category. Of the 25 respondents, 20 students (80%) rated the module as 'very practical' with a score range of 90–100, whilst 5 students (20%) rated it as 'practical' with a score range of 80–89. Overall, this distribution of scores demonstrates consistent positive results between the initial test and the field test, suggesting that the VisioBody AR-assisted anatomy module can be considered to have a high level of usability in a real-world learning context.

In terms of student feedback on the module, the dissertation data reveals a very positive trend. In small-group tests, students stated that the medium was interactive, user-friendly and greatly aided understanding, as the visualisation of the material via AR was clear. Students also showed a high level of interest in AR visualisation, particularly because anatomical objects could be observed in a more concrete manner than with conventional media. The results report states that students found it easier to understand the structure of bones and muscles, and the module content was considered to be aligned with the learning objectives. In the larger group, positive student feedback was also evident in the assessment reason "very practical", namely the ease of use of the module, the intuitive interface, the clear and immersive 3D visualisation of the musculoskeletal system, the stability of marker navigation, and the integration of content and exercises that aid understanding of the concepts of bones, muscles and joints. In terms of ease of use, the results of the usability tests showed that the module was relatively easy for students to operate, both in the initial stages and during wider implementation. In small-group testing, the module was rated as easy to use, although some students still needed time to adapt in the early stages in order to familiarise themselves with the AR application's features. Another technical issue that arose was the difficulty in scanning markers when lighting in the learning environment was inadequate. Similar findings were also observed in the larger group. Five students who assessed the module solely in the 'practical' category stated that the module was indeed easy to use, but that the use of some AR features still required initial adjustment and that object tracking consistency was still affected by lighting conditions. This means that, in terms of ease of use, the module is already good, but the technical stability of the application and user readiness still need to be strengthened.

In terms of visual appeal, the main strength the module focuses on the three-dimensional visualisations presented via the VisioBody AR app. In the small group, the AR visualisations were rated as having clear resolution and were found to directly enhance students' interest in learning. In the large group, students' assessment that the module was highly practical was also linked to the clear and immersive quality of the 3D visualisations of the body's movements, the intuitive interface, and the stable marker navigation. Consequently, the appeal of the module's presentation stems

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not only from its aesthetic qualities, but also from its visual qualities, which facilitate a concrete exploration of anatomical structures. This makes students more engaged in their studies, whilst also helping them to grasp the abstract and spatial nature of the anatomical material more easily.

In terms of the clarity of the material and the instructions for use, the results of the usability test also showed positive outcomes. The small-group test was specifically designed to assess the clarity of the instructions, the comprehensibility of the material, and the layout. The results indicate that the module's content aligns with the learning objectives and aids students' understanding of the anatomical material. In large groups, practicality is also supported by the integration of content and exercises, making anatomical concepts easier to understand. Nevertheless, there is still some feedback regarding the user guide, particularly the need for a brief guide for novice users and the need for additional support, such as video links to case study questions in the printed module. These findings indicate that the module content is sufficiently clear, but the user instructions could be improved to ensure a smoother learning experience for students from the outset.

The results of the practicality test demonstrate that the VisioBody AR-assisted anatomy learning module falls into the 'highly practical' category. This finding is supported by two key findings. Firstly, in the small group, the average score was 92.4, with 13 out of 15 students rating it as 'very practical'. Secondly, in the large group, the average student score was 83.6, with 20 out of 25 students rating it as 'very practical'. This practicality is underpinned by four key factors: positive student feedback, the module's ease of use, engaging 3D visuals, and the clarity of the content and instructions. On the other hand, improvements are still required regarding the initial adaptation phase, the stability of marker scanning in low-light conditions, and the strengthening of the user guide. Thus, this module meets the criteria for practicality as an anatomy learning tool ready for use by Physical Education and Sports Science students at Hamzanwadi University.

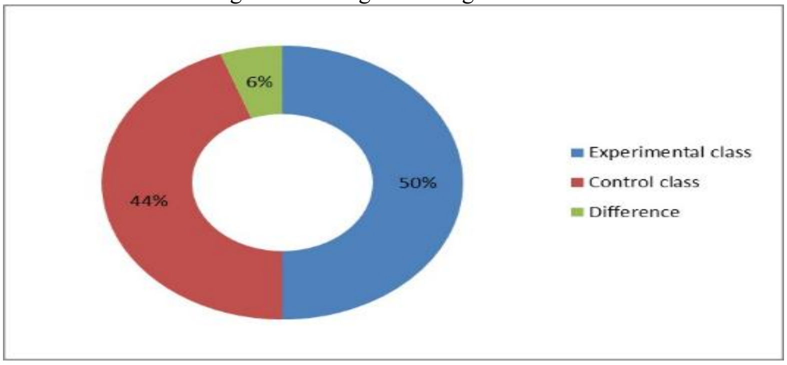
4.3. Results of the effectiveness test on improving student learning outcomes

Table 2: Module Effectiveness Data

Components	Experimental class	Control class	Description
Number of students	35	35	Total number of participants: 70 students
Measurement Design	Posttest-only	Posttest-only	There are no pre-test scores in the effectiveness table
Average learning outcomes (post-test)	76,59	68,08	Higher experimental class
Average difference	-	8,51	76,59 − 68,08

This table shows that the average post-test score for the experimental class is higher than that of the control class. The difference in average scores of 8.51 points serves as empirical evidence that students who studied using the VisioBody AR-assisted anatomy module achieved better learning outcomes than those who studied using the conventional module.

Figure 1: Average Learning Outcomes



This diagram confirms the superiority of the experimental group over the control group in terms of final learning outcomes. This difference serves as evidence that the use of AR modules yields better results than conventional teaching methods.

Table 3: Pre-test and post-test scores

Components	Report findings	Value
Post-test for the experimental class	Reported	76,59
Post-test for the control group	Reported	68,08

Table 4: Results of the prerequisite analysis

Prerequisite test	Group/Test basis	Statistical values	Sig.	Decision
Kolmogorov–Smirnov normality	Experiment	0,099	0,200	Normal
Shapiro–Wilk normality test	Experiment	0,981	0,800	Normal
Kolmogorov–Smirnov normality	Control	0,120	0,200	Normal
Shapiro–Wilk normality test	Control	0,959	0,212	Normal
Homogenitas Levene (based on mean)	Experiment vs control	1,725	0,194	Homogen

All significance values for the normality test were above 0.05, indicating that the learning outcome data for both groups are normally distributed. The homogeneity test also yielded a p-value of $0.194 > 0.05$, indicating that the variances of the two groups are homogeneous. As these two conditions are met, parametric analysis to test the effectiveness of the module may proceed.

Table 5: Results of the statistical test of effectiveness

Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5,066,004	1	5,066,004	27,6016	0,000
Within Groups	1,248,071	68	18,354	-	-
Total	6,314,075	69	-	-	-

The ANOVA results show $F = 276.016$ with Sig. = 0.000, indicating a significant difference in learning outcomes between the experimental and control groups. Statistically, this means that the use of the VisioBody AR-assisted anatomy module has a significant effect on students' learning outcomes.

Table 6: Effectiveness rate of the module

Effectiveness indicators	Value	Interpretation
xperimental group's post-test mean > control group's	76,59 > 68,08	Modules are superior to conventional learning
Average difference	8,51 poin	There are clear benefits to learning
Statistical significance	p = 0,000	The difference is very significant
Status of module effectiveness	Effective	The module has been declared effective

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Based on average learning outcomes, score differences and statistical tests, the VisioBody AR-assisted anatomy module was found to be effective. The abstract and summary of the dissertation state that this module is effective as a virtual laboratory that helps reduce cognitive load and reinforces the relationship between anatomical structures and motor function.

5. DISCUSSION

The development of AR-based modules can improve learning outcomes because this product is not designed solely on the basis of technological logic, but rather on pedagogical logic. The discussion of these findings explains that the design of VisioBody stems from a real problem faced by Physical Education and Sports Science students, namely the difficulty of simultaneously constructing spatial relationships between bones, joints, muscles and movement. Consequently, the printed modules and the AR application have been designed as a single, mutually reinforcing learning system: the modules provide a conceptual framework, a sequence of content, exercises and assessment, whilst the AR provides concrete, interactive visualisations. This explanation is consistent with the constructivism of Piaget (Devi, 2019) as students construct knowledge through active interaction with learning materials; it is also consistent with Brookfield, (2021) concept of *self-directed learning*, as the module provides scope for independent study; and it aligns with Branch & Varank, (2009) ADDIE model, which requires coherence between needs analysis, design, development, implementation, and evaluation. In a broader context, these findings are also consistent with the meta-analysis by Garzón et al., (2020) which found that AR has a positive effect on learning effectiveness, as well as with the review by Ibáñez & Delgado-Kloos, (2018), which identifies AR as a means of enhancing conceptual understanding and affective outcomes when combined with appropriate instructional strategies. In other words, the improvement in learning outcomes in this study stems from the integration of design, content, media, and learning activities, rather than from the novelty of the technology alone.

3D visualisation aids the understanding of anatomy, as anatomy inherently requires representations of space, orientation, depth and spatial relationships that are difficult to convey through two-dimensional images alone. The thesis states that VisioBody is designed to transform static 2D media into dynamic 3D visual representations; objects can be rotated, zoomed in on, zoomed out, and overlaid, allowing students to observe anatomical positions, the relationships between bones, joints and muscles, and the mechanisms of movement through interactive manipulation. From a theoretical perspective, this is fully consistent with the Paivio & Clark, (2006) the visual system supports spatial processing, whilst the verbal system reinforces conceptual structures and terminology. When both are present simultaneously, students no longer merely memorise the names of structures, but build a functional understanding that can be applied in practice. These findings are also consistent with R. E. Mayer, (2002) Cognitive Theory of Multimedia Learning which views learning from words and images as a means of forming stronger mental connections, and with Sweller, (2011) as appropriate visualisation can reduce *extraneous load* resulting from the need to integrate separate text and images oneself. Empirically, the findings of this study are consistent with those of Dreimane and Daniela (2021), who state that AR makes anatomy learning more interactive than 2D teaching aids; with Tang et al., (2020), who note the rapid growth of AR in medical education; and with García-Robles et al., (2024), who report that XR in anatomy education outperforms textbooks, atlases, and didactic lectures in many learning contexts. Therefore, 3D visualisation in this study is not merely a cosmetic feature, but rather a key mechanism that helps students construct more precise anatomical mental models.

he interactivity of the module boosts students' motivation and engagement, as it transforms the experience of learning anatomy from a passive reading activity into a dynamic visual exploration. This study notes that the initial challenges in teaching anatomy in the Physical Education and Health Education programme are linked to low levels of motivation to learn; the section on pedagogical implications emphasises that the VisioBody AR module enhances the quality of the learning experience through a more exploratory, interactive and contextual approach to learning. Students do not merely view images, but scan markers, observe 3D objects, match labels with shapes, and link structures to sports movements. This approach is closely aligned with Kolb et al., (2014) of experiential learning as knowledge is formed through concrete experience, observation, conceptualisation, and testing within a dynamic context. More technically, this kind of interactivity is also consistent with the characteristics of AR described by R. Azuma et al., (2022): virtual objects are present in the real environment interactively and in real time. Empirical evidence from other sources also supports these findings. A review by Dreimane & Daniela, (2021) notes that AR makes the study of anatomy more engaging and motivates students to be more active in the construction of knowledge. A meta-analysis by Chen & Zhang, (2025) reports that AR/MR in medical education enhances *perceived usefulness*, *perceived ease of use*, and *enjoyment*, although the impact on knowledge is not always automatically significant. Liu & Hou, (2021) review also summarises that AR supports attention, motivation, mental rotation, self-confidence and learning satisfaction. In this regard, the dissertation's findings which highlight reduced learning fatigue and increased student attention are entirely plausible, as interactivity shifts students' focus from memorising terminology to observing and interpreting the meaning of anatomical structures.

The findings appear to be strongly supported by existing theory and research in four key areas. Firstly, the dissertation's findings regarding reduced cognitive load are consistent with Sweller's Cognitive Load Theory and with the principles of coherence, signalling and segmenting in Mayer's multimedia theory; when anatomical material is well-organised and visualised proportionally, students do not need to expend mental energy to integrate separate sources of informationSecondly, the findings regarding the strengthened association between anatomical structure and motor function are consistent with Dual Coding Theory, as the integration of visual and verbal channels enhances encoding and retention. Thirdly, the findings regarding the enhancement of exploratory and contextual learning experiences are consistent with constructivism and Kolb's learning experience, as students learn by interpreting, testing and linking anatomical representations to motor situations. These findings are also consistent with Bork et al., (2021) regarding the potential of collaborative AR in anatomy, as well as with Tan et al., (2022) who position visual-immersive media as a solution to the limitations of conventional anatomy teaching.

These findings should also be interpreted with caution. The international literature indicates that AR does not always directly lead to cognitive advantages across all studies. A meta-analysis by Zhiqing, (2015) found that, overall, AR/MR was more consistently effective at improving skills, ease of use and enjoyment of learning than knowledge; however, in subgroups where students received direct tutor guidance, knowledge scores increased significantly. This finding is significant because it aligns with the central argument of the dissertation: effectiveness arises when AR is integrated into systematic instructional design, rather than standing alone as a standalone application. This is where this research makes its contribution. VisioBody is not used merely as a temporary demonstration tool, but as a core component of a module that combines text, 3D visualisations, user guides, exercises and assessment. This structure ensures that AR operates within a pedagogical framework, rather than simply as a technological tool. Therefore, this study not only confirms the benefits of AR, but also clarifies the conditions necessary for those benefits to be realised, namely the alignment of learning objectives, the organisation of content, visual scaffolding, exploratory activities, and the assessment of learning outcomes.

In summary, the findings of this study can be interpreted as evidence that AR-based anatomy modules enhance learning outcomes by combining a systematic module structure, manipulative 3D visualisations, interactivity that sustains attention, and theory-based instructional design. 3D visualisation helps students understand the spatial relationships of the body, interactivity enhances motivation and focus, whilst verbal-visual integration aids the mastery of terminology and functional meaning. Therefore, the results of this study are not only consistent with constructivist theory, CTML, CLT, and *dual coding*, but also reinforce international findings that position AR as the most effective medium when designed for specific learning needs. In the context of the Physical Education, Health and Recreation programme at Hamzanwadi University, the

VisioBody module has successfully transformed anatomy a subject that was previously abstract and difficult to visualize into a concrete, contextual learning experience that is more closely aligned with the needs of sports movement analysis.

For lecturers, the findings of this research provide an innovative alternative teaching resource for anatomy lessons. The dissertation explains that lecturers are advised to integrate the VisioBody AR-assisted anatomy module into a variety of teaching strategies, such as project-based learning, problem-based learning, or blended learning. The implications extend not only to the ease of explaining abstract anatomical concepts, but also to the development of students' critical thinking, collaboration and digital literacy skills. Consequently, lecturers are provided with teaching materials that not only explain the subject matter but also support active and more contextual learning.

For students, this module serves as a self-study resource that can be used not only during lectures but also as a supplementary learning tool outside the classroom. This study strongly recommends that students use the VisioBody module not only as their primary learning resource, but also as a supplementary tool to reinforce their understanding of the subject matter and enrich their learning experience in anatomy classes. Students are encouraged to actively explore AR features, engage in discussions, and put the anatomical concepts they have learnt into practice, so that the knowledge they gain becomes more in-depth and applicable in the field of physical education. This implication is significant because the module is no longer viewed as a passive reading resource, but as a tool for self-directed learning that helps students develop conceptual, visual-spatial and functional understanding in an integrated manner.

From an educational perspective, lecturers gain access to innovative teaching materials that enhance active learning. In practical terms, students gain access to interactive and practical self-directed learning resources. At an institutional level, universities gain a model for technology integration that can be adopted to modernise the curriculum and strengthen digital literacy. In this research framework, the development of the VisioBody AR module has even reshaped the paradigm of anatomy teaching in physical education: anatomy is no longer treated as a course based on the rote memorisation of terminology, but rather as the foundation for the analysis of movement, which is explored through visual exploration, the manipulation of objects, and the construction of spatial schemas grounded in cognitive theory.

CONCLUSION

This research has produced the VisioBody Augmented Reality (AR)-assisted anatomy learning module, designed to support the study of the musculoskeletal system among students on the Physical Education, Health and Recreation (PJKR) programme at Hamzanwadi University. The developed product combines printed modules with interactive three-dimensional visualisations, enabling the study of anatomical positions, bones, joints, and muscles in a more concrete, systematic, and contextual manner.

In terms of validity, the module has been deemed valid based on the assessment results of subject matter, media and language experts. This validity indicates that the module's content, presentation quality and integration of AR applications are in line with the curriculum requirements, student characteristics and learning objectives for anatomy within the Physical Education and Health Education (PJKR) context.
From a practical perspective, the module has been found to be practical for use in teaching. Students and lecturers are able to understand the instructions, make use of the AR features, and follow the learning pathway effectively. This indicates that the module is not only academically sound, but also easy to implement in real-world learning situations.

In terms of effectiveness, the VisioBody AR-assisted anatomy module has been shown to effectively improve students' learning outcomes. Statistical tests revealed a significant difference between the experimental group and the control group with $p = 0.000$, whilst the average learning outcome of the experimental group reached 76.59, higher than that of the control group at 68.08. These results confirm that the use of the AR module has a positive impact on students' conceptual understanding, analytical skills, and motivation to learn.

In essence, the effectiveness of this module lies in AR's ability to provide interactive 3D visualisations that help students overcome spatial representation barriers, facilitate the mastery of complex anatomical terminology, and reinforce the relationship between anatomical structures and motor functions. In this context, the AR VisioBody module serves as a virtual laboratory that supports a more immersive, self-directed and meaningful approach to learning anatomy.

It can therefore be concluded that the VisioBody AR-assisted anatomy learning module is valid, practical and effective as an innovative teaching resource for improving the learning outcomes of Physical Education and Health Education students at Hamzanwadi University. This study also confirms that the integration of AR into the instructional design of anatomy courses makes a tangible contribution to enhancing independent learning, digital literacy and the quality of technology-based learning in higher education.

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