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Development of team-based project learning media for 3D body mechanics animation course

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ABSTRAK

Penelitian ini bertujuan mengidentifikasi kendala dan mengembangkan solusi untuk meningkatkan efektivitas pembelajaran mata kuliah Animasi 3D: Body Mechanic di program studi D4 Animasi Universitas Negeri Malang. Metode penelitian menggunakan model ADDIE (Analysis, Design, Develop, Implement, Evaluate) dengan pendekatan Team-Based Project dan blended learning. Hasil penelitian menunjukkan bahwa mahasiswa mengalami kendala berupa keterbatasan perangkat keras, ketidaksesuaian versi perangkat lunak, serta kesulitan memahami tutorial asing. Untuk mengatasinya, dikembangkan media pembelajaran interaktif dalam LMS SIPEJAR yang menyediakan tutorial berbahasa Indonesia, infografis, dan model karakter sederhana. Hasil evaluasi menunjukkan bahwa media pembelajaran yang telah dikembangkan dan terorganisir dalam LMS SIPEJAR dengan didukung model pembelajaran team-based project, telah secara merata dan signifikan meningkatkan hasil belajar mahasiswa di bidang animasi tiga dimensi. Penelitian kedepan perlu melihat diferensiasi hasil belajar masing-masing individu untuk melihat lebih mendalam perkembangan kompetensinya serta perlu adanya mekanisme umpan balik antar mahasiswa (peer feedback) agar mereka lebih mandiri dalam menyelesaikan proyek kelompok.

ABSTRACT

This study aimed to identify challenges and develop solutions to enhance the effectiveness of the 3D Animation: Body Mechanic course in the Animation program at Universitas Negeri Malang. The research applied the ADDIE (Analysis, Design, Develop, Implement, Evaluate) model combined with a Team-Based Project and blended learning approach. The results indicate that students face hardware limitations, software version mismatches, and difficulties understanding foreign-language tutorials. To address these issues, the learning media was developed within the LMS SIPEJAR, providing tutorials in Indonesian, infographics, and simplified character models. The evaluation results indicate that the learning media supported by the team-based project learning model has significantly and evenly enhanced students' learning outcomes in three-dimensional animation. Future research should explore the differentiation of individual learning outcomes to gain deeper insights into their competency development and establish a peer feedback mechanism to encourage greater independence in completing group projects.

INTRODUCTION

The Body Mechanics Animation is grounded in complex concepts of the body's mechanisms during movement. With biomechanical principles, the animation aims to imitate the motions of the human body realistically as well as accurately. According to Sasmito, et al. (2021), biomechanics is the application of mechanics in biology, the discipline more specifically focused on the bodies of living organisms. The animators can create the most believable and convincing scenes since they deeply understand how joints, muscles, and the skeletal system work together during physical activities. This can be achieved not just in the movement but also where speed, balance, and expression of emotion come into play in shaping intimate and realistic visual narratives. Thus, Body Mechanics Animation is an effective way of creating eye-catching images and capturing the essence of human movement to transmit deeper and more meaningful stories.

Body Mechanics is, in fact, the bedrock upon which good natural and believable animations lie for the animator. If animators understand how the human body moves and interacts, they can produce more realistic and impactful effects. Body proportions, motion mechanics, and emotional expressions are some of the most vital principles of bringing characters to life on screen. By utilizing these principles, animators create more interesting and complex scenes that are visually alluring and effective in delivering a message or emotion to the audience. Without this understanding, an animator's role may easily be replaced by motion capture software and hardware or artificial intelligence. With the increasing availability of tools that capture Body Mechanics and Facial Animation, the animator's role may diminish (Sharma, as cited by Limano, 2021). Therefore, a deep understanding of Body Mechanics is not merely an additional skill but a critical necessity for animators aiming to produce high-quality works.

The "3D Animation: Body Mechanics" course crucially supports students of the Animation Program at Universitas Negeri Malang in achieving graduate profiles, particularly as Motion Designers and Development Artists (Fakultas Vokasi UM, 2023). In this context, an in-depth understanding of Body Mechanics principles is an essential foundation for training students to become competent professionals in the animation field. By studying 3D animation focusing on Body Mechanics, students learn to understand how the human body moves and reacts in various situations. For Motion Designers and Development Artists, mastering these principles is key to creating engaging animations that effectively communicate messages to audiences. This, therefore, becomes a course that teaches technical skills and helps students develop creativity and deep insights into the essence of 3D animation.

The "3D Animation: Body Mechanics" course, under the Animation Program, applies a Project-Based Learning (PjBL) model. The objective of a PjBL arrangement is to sensitise students to meaningful learning experiences in which they are engaged in project-based processes and produce a final product (Kemendikbud Pusdatin, 2020). The model is particularly beneficial for this course because students undertake tasks similar to those in industry workflow, directly introducing them to a real professional environment. Further, to nurture teamwork, PjBL has adapted itself into a Team-Based Project format.

At the end of this course, every student will work with either an individual or a team in the final project work. Before starting the project, they will attend training on animating body movement using principles of Body Mechanics. This course will run for three credits with a total learning time of 510 minutes a week, following the standards set by the Kementerian Pendidikan dan Kebudayaan RI (2020). Of these minutes, 200 are allocated for a class with instructors, whereas the 310 minutes are for independent learning. Yet they do not comply with the independent-learning mode mentioned, as they still lack proper guidance and resources, making learning with them not so effective. This led to research in developing materials for learning under this heading, part of 3D Animation: Body Mechanics which supports independent study. The learning materials have also been integrated with different types of courses that are part of the SIPEJAR Learning Management System (LMS). The goal shall thus be fostering independent learning and research to reveal its salvation in terms of learning outcomes for students.

Spiller (2022) found in the research entitled Team-Based Learning in an Art and Design First-Year Studio Class that the TBL method improves the process of learning by strengthening students' engagement, encouraging participation among students, and better understanding of learning content within students-centered discussions. Kuo et al. (2021) also added that the effects of web-based MOOC development in learning are behavior, emotion, and cognition of the learners. Further, Pan and Guo (2020) discussed the online 3D animation learning design and showed that 3D animation learning can be done independently in the online environment. This is possible due to its visually rich environment, the ability to translate abstract concepts through simulations, fully virtual learning objects, and the presence of scenarios. These three studies serve as the foundation for directing this research.

The objectives of this research are (1) to design learning media for the 3D Animation: Body Mechanics course tailored to the Team-Based Project learning model and (2) to evaluate the effectiveness of the developed media. This research focuses on the Animation students at Universitas Negeri Malang from the 2021 and 2022 cohorts.

This study contributes to enhancing 3D animation education, particularly in Body Mechanics, by developing project-based learning media using the Team-Based Project model integrated into the SIPEJAR LMS platform. It is designed to support independent learning, addressing the previous lack of guidance, and offering learning experiences relevant to industry needs. By incorporating biomechanical principles and collaborative approaches, the research helps students understand body movements realistically, create high-quality animations, and improve their competencies as Motion Designers and Development Artists. Moreover, the study promotes the effectiveness of project-based digital learning, enriching students' technical understanding and creative skills.

METHOD

This study employs the ADDIE (Analysis-Design-Develop-Implement-Evaluate) research and development method, as shown in Figure 1. Although the model appears linear, ADDIE inherently has interconnected components and is iterative and cyclical (Trust & Pektas, 2018). This model was chosen because it is systematically designed to develop technology-based learning, such as 3D animation body mechanics. ADDIE ensures that 3D animation body mechanics learning is developed and implemented in a systematic, iterative, and measurable way. As such, ADDIE fits this research because it takes holistic stakeholder needs into account and makes available and effective solutions to the learning challenge.

The analysis of the data collected via observation and interview with erstwhile students of 3D Animation: Body Mechanics will more effectively set parameters for defining and connecting within relevant literature the problems faced. It also generates ideas for relevant learning media for those students enrolled in this course. Collected data will then formulate what's known as a needs analysis. This critical analysis examines collected data and assesses appropriate learning strategies and the development of learning media.

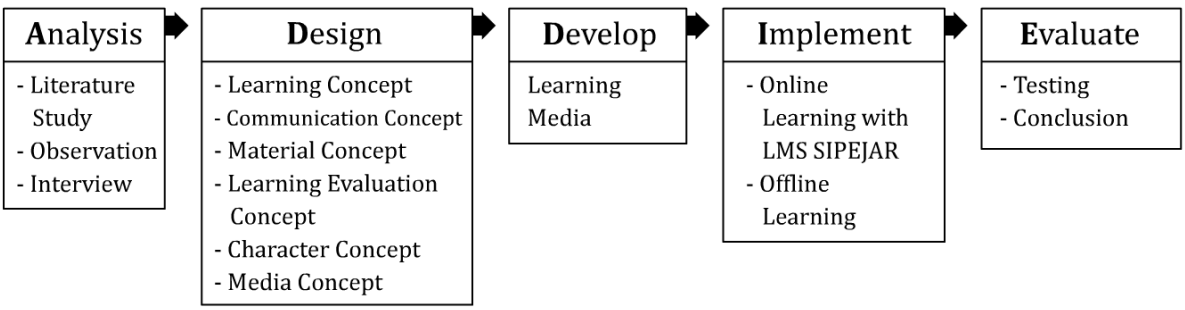

Figure 1. Research and development method based on ADDIE model

The design stage concentrates on various product developments or environments (Usfinit et al., 2024). The need assessment results would be translated into concepts such as storyboards,

visual asset designs, setting up locations or settings for material production, and assembling tools and materials for the production process.

The develop stage involves making the production, which comprises the making of several learning materials by the development team based on the concept from the design stage, such as syllabus (RPS), teaching modules, presentation slides, 3D character models, infographics, and assessment tools. The next step (implementation) is uploading developed learning content on an integrated learning platform such as the SIPEJAR LMS. This ensures that students are granted easier access to learning materials and can participate fully in the learning process.

The last stage entails evaluation, wherein the use of the products is put within the learning system to test their effectiveness. The experiment was conducted among 62 students from two classes who participated in the 3D Animation: Body Mechanics course. The evaluation was done through a pretest in which the learning situation and media remained as usual, followed by a post-test, which controlled the learning situation and media to compel the students to use the developed learning media.

The pre-test and post-test results were then compared and analyzed using Cohen's D (standardized mean difference) to find out the effect of the developed learning media on students' learning outcomes. This evaluation presented feedback on how effective the developed media were and how they add value to students' learning experience and outcomes.

RESULT

Analysis

As observation and interviews reveal, students face obstacles in learning animation techniques of 3D body mechanics. This ingesting process indicates many findings, such as restricting access to devices suitable to one's learning, as well as the lack of software version consistency. Furthermore, it is challenging for the learner to understand foreign-language tutorial videos, especially, when it is used with another version of software within the campus. Research evidence found that an adequate number of devices with high performance and synchronized software within the simulation-based education context significantly contributed to learning efficiency (Karadoğan et al., 2019).

Language barriers also raise their heads as a major constraint. Underscores Cervera (2024), that developing instructional materials in the local language will lead to better understanding and engagement of students in technology-based learning. Foreign/tutorials must be relevant to and accessible for students having trouble with foreign-language access materials. Also, Waskito et al. (2024) discovered that software version incompatibilities within campus software make lectures confusing for students. This raises questions about the need for institutions to ensure software synchronization.

This online learning model has limitations, which translate into difficulties, particularly in a practical course such as 3D animation. According to a study conducted by Low et al. (2023), students learn better in practice-based learning when they attend face-to-face one backed up with constant evaluation sessions. The study concluded that students preferred to consult the instructor because they would rather raise any issue bothering them in real time. There are several issues worth mentioning from the data about learning 3D body mechanics animation. Some of them are language challenges, variations in software versions, lack of accessibility to correct devices, and the need for more intensive guidance and evaluation. To improve the quality of learning, several corrective measures can be implemented:

- Developing Learning Materials in Indonesian as many students struggle to understand foreign-language tutorials, it is essential to create instructional content in the local language.
- Software Synchronization: instructors should ensure that the software versions used in tutorials align with those available to students to reduce confusion caused by differences in procedures.

- Hardware-Supportive Software: the software used in learning should be compatible with the hardware specifications accessible to students.

The learning process has to have the performance of an instructor who is quite up to par with the students involved. Having an overall manual could make the learner grasp everything thoroughly. Providing frequent formative assessments and feedback about students' animated works would be especially helpful in assessing what students should improve upon and hone further. All in all, the expected results of implementing this approach would be a more effective and efficient process for learning 3D body mechanics animation.

Design

Acknowledging the previously mentioned obstacles in the 3D Animation: Body Mechanics course, in particular, the problems at the design stage have described essential aspects like Learning Concept, Communication Concept, Material Concept, Learning Evaluation Concept, Character Concept, and Media Concept.

1. Learning concept

As highlighted by Jirapanthong (2021), project-based learning (PPL) is a potent tool that can help enhance learning outcomes. Hickman (2024) stated that team-based teamwork has significance in animation projects and the support provided by technology in team performance. PBL in 3D Animation: Body Mechanics involves students working together using problem-solving as a centerpiece in class to help build their understanding of bodily movement concepts, as found in the work of Yu, Roush, and White (2024). The study employed Team-Based Project Learning, where different teams accomplish specific animation concentration projects within the breadth of body mechanics. The course combines face-to-face (offline) and asynchronous school-based online learning facilitated through the SIPEJAR Learning Management System (LMS), where the primary platform covers over 16 sessions.

In-person classes are held every week for 4 hours, during which lectures relate to the basics and techniques in the use of 3D animation, with emphasis on body mechanics applications. Along with practice, students share knowledge during collaboration. Instead of allocating formal time for discussions, the lecturer provides interim feedback for different groups on their collective progress to ensure that they are on course.

Asynchronous online learning enables students to learn independently through the online materials uploaded in SIPEJAR, comprising e-books, tutorial videos, reference images, and animation illustrations. Learners submit their outcome projects through the LMS and use the online discussion forums for consultation with the instructors. This method is flexible enough to allow timelines for learning while not interfering with the team's effectiveness and academic interaction.

The project-based learning model aims to hone the students' technical skills in 3D animation, particularly their knowledge of body mechanics and application. Moreover, it exposes the learners to teamwork, project management, and communication, pretty much everything that a professional has to deal with in a workplace setting. The SIPEJAR Learning Management System helps with effectively monitoring the progress and evaluation performance.

A full-fledged learning experience provided through this problem-based learning approach combines synchronous in-person sessions with asynchronous online learning. This model enables students to acquire technical skills and develops teamwork and adapting abilities in a digital learning environment. This blended learning model facilitates the student with training in industry-relevant education dealing with doing work as part of a group and learning independently.

2. Communication concept

It is intended for learning media to address the profiles of students:

Demographic profile:

(a) Is in the fourth semester, aged 19-21.
(b) Is in Animation programs or related fields.
(c) Living in Malang area for easy access to the sessions.

Psychographic profile:

a) Having a background with experience in drawing, design, 2D animation, and 3D modeling shall equip the learner with the foundational skills prior to animation for 3D body mechanics.
b) Motivated to work as a team and wanting to improve technical animation skills.

E-books, tutorial videos, reference images, or animation demonstrations -various learning materials are available on SIPEJAR LMS. It has made access to these resources around the clock, thereby enabling students to study at their own pace. Additionally, an online discussion forum serves as a communication platform for consultations and periodic feedback, enabling students to iteratively improve their work.

During project implementation, software synchronization between campus resources and tutorials is emphasized to avoid confusion and ensure consistency in learning, as highlighted by the study of Waskito et al. (2024). Furthermore, instructors are encouraged to select software compatible with students' device specifications to prevent technical difficulties.

Language barriers in tutorials often pose challenges for students. Cervera (2024) suggests that developing instructional materials in the local language can enhance student engagement and understanding. Therefore, tutorial videos and supporting materials will be prepared in Bahasa Indonesia to aid the learning process effectively.

3. Material concept

The course in 3D Animation: Body Mechanics offers students a combination of theoretical knowledge to practical know-how in creating realistic animations through 3D software. This provision sets out the different sessions of theory and practice complemented with team-based project activity wrapped in blended learning, with the SIPEJAR LMS platform allowing participation for some sessions as well as asynchronous online learning.

The early sessions expose students to the general concepts of animation, navigation of 3D software, RPS on the course (syllabus), and instructional modules. Planning and Block techniques follow, as well as Spline and Polish, to finesse transitions between movements. Including an understanding of the application, jumping, kicking, and lifting activities are clarified concerning body mechanics and dynamic motion.

Students will learn advanced animation such as traditional or modern dance, lip-sync animation, and choreography fight scenes, which will teach them blocking and polishing techniques. Each class is joined with an explainer video, presentation slides, motion graphics, and graphics infographics for students' better understanding of the contents. It also provides for instructor-student peer interaction through the discussion forums of SIPEJAR. Therefore, contributing to regular feedback and continued improvement of their animation projects.

Research by Azadi et al. (2023) also highlighted how digital media, such as videos and motion graphics, could elucidate very complex movements to students. Similarly, derived from the same work, Bargteil et al. (2020) pointed out that body mechanics, along with physics-based animation techniques, could be learned by students because of their scientific understandability concerning animated motion. Kwiatkowski et al. (2022) also established that employing project-based learning and reinforcement learning components in animation education has increased student involvement and prepared them well for industry challenges.

4. Learning evaluation concept

Instructors can give direct feedback and clarify misconceptions through weekly in-person sessions to do regular assessments. This concept supports the findings of Han et al. (2021), who emphasized the importance of real-time feedback toward achieving learning goals, especially in collaborative and practice-based education.

Through this combination of face-to-face and online asynchronous learning, students can better develop teamwork, project management skills, and critical skills necessary in the professional industry. This assists in effective learning for 3D animation body mechanics, both in terms of time and efficiency, for an improvement of the technical and professional skills of the students.

5. Character concept

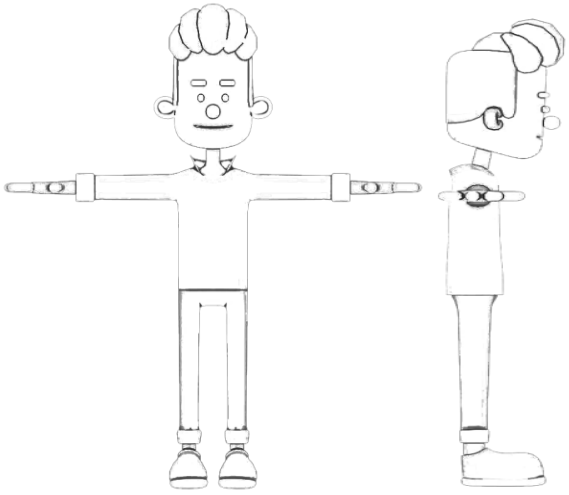

Figure 2. Character concept for student animation project

The figures in the 3D Body Mechanics Animation course were made with the researchers keeping the technological and psychological aspects in mind (see Figure 2). The characters have been slim in categories, making the body mechanics easy to animate, as students will be allowed to appreciate and focus on movement and the simple techniques associated with it. Also, the character's design is similar to that of a young adult, which meets the target audience of students aged 19-21 in the 4th and 5th semesters. This enables students to empathize and participate more in the animation process.

The character design not only serves as a learning tool but is also a representation of the students themselves. Characters with potential resonance with the audience as noted by Arshad et al. (2019) result in a better level of engagement and learning effectiveness in animation. Further, a simplified and proportionate character increases students' learning regarding body mechanics application.

Hoyet (2022) gives a positive aspect on how a character with a very simple and light design facilitates easy rigging and animation simulation for students. Proper rigging enables students to undergo animations concerning basic movements, like walking, jumping, and running. These designs provide an opportunity for a better understanding of animation techniques without worrying too much about the complex aesthetic details.

6. Media concept

The Body Mechanics in 3D Animation course makes use of the SIPEJAR Learning Management System (LMS) to provide content, communication, and assessment. SIPEJAR Learning Resources include modeled digital resources such as e-books, video tutorials, infographics, audio resources, and animation samples, all of which should supplement student learning. The blended learning course takes place face-to-face and through asynchronous online learning, thus offering students temporal and locational flexibility.

Each session of the course is planned to contain specific materials. The early meetings introduce students to the Semester Learning Plan (RPS) and a 3D character model for the PIC training. The following sessions cover blocking and polishing, delivered through various forms of visual media such as explanation videos, motion graphics, and infographics. More advanced topics will be covered, such as jumping, kicking and lifting, and dancing animation. In addition, there will be interactive instructional videos to support improving comprehension of body mechanics techniques. Mid-term and final exams will be done to measure the learning outcomes.

It is the present course that uses Blender as the primary software platform since it is lightweight and user-friendly, so it is accessible even on laptops or PCs with low specifications. It is an open-source software that provides all functionalities for modeling, rigging, animation, and rendering, suiting the educational model. Students would be able to use it without any charges, and there would, therefore, not be any requirement for expensive licenses or specialized

hardware. Besides, its friendly interface serves all ranges of skills -from beginner to advanced level users for an effective workflow in animation.

Blender application does critical animation processes like blocking, splining, and polishing: it speaks about the realistic steps of body mechanics coursework. Comprehensive tutorials and a robust global community allow one to rely on independent learning while simultaneously, minimizing technical difficulties caused by hardware limitations, ideal for further personal development of students' technical competencies and learning experience.

Develop

For studying 3D animation on Body Mechanics, the teaching and content development crews created components necessary to aid this course's teaching and learning process (whole processes can be seen in Table 1 and the 3D models are in Figure 3). The Semester Learning Plan (RPS) is one of the components, which contains designs for course delivery in a more general view, including learning outcomes, ways of assessing, and topics to cover for every session. Another product of this stage is the teaching module, which assists the lecturers in leading students through subject matters and assignments, clearly indicating how students will progress through the learning process.

Also included in the learning content are presentation slides as the primary medium that is used for teaching theoretical concepts in every session, be it live or virtual. However, simple yet very flexible 3D characters were designed for practical purposes so that students can focus on the area of application of body mechanics actions in jumping, kicking, and dancing, as per the syllabus (RPS).

In addition to these, supportive media such as infographics and moving graphics have been developed to concretize and buttress the understanding of complex concepts students grapple with. Infographics are short, crisp content summaries and moving graphics are recourse resorted to, efficiently explaining the dynamics of animation movements. Both media are available under SIPEJAR LMS to enable independent students' learning. Sutrisno et al. (2023) noted that interactive media, including 360-degree videos and motion graphics in animation learning modules, have proven to lead to better engagement and richer understanding by students of animation principles.

In this stage, assessment tools are being prepared, including rubrics, quizzes, performance tests, and evaluation instruments for midterm (UTS) and final examinations (UAS). These are to be prepared in accordance with project-based learning methods so that the mentors can deliver continuous feedback on the performance of every student. Thus, as comprehensive and varied content is developed, it is hoped that the learning process will run more effectively in enabling students to realize their goals in animating skills.

Figure 3. The developed 3D character model

Table 1. The developed learning resources and media

Meeting	Learning topic	Learning resources and media

1	Introduction	RPS (syllabus) Learning module Material slides 3D model character
2	*Planning & blocking*	Material slides Video explainer Motion graphic Infographic
3	*Splinning & polishing*	Material slides Video explainer Motion graphic Infographic
4	Character jumping 1: *blocking*	Material slides Video explainer
5	Character jumping 1: *polishing*	Material slides Video explainer
6	Character jumping 2: *blocking*	Material slides Video explainer
7	Character jumping 2: *polishing*	Material slides Video explainer
8	Midterm exam	Material slides Assessment tools
9	Kicking: *blocking*	Material slides Video explainer Infographic
10	Kicking: *polishing*	Material slides Video explainer
11	Weight lifting: *blocking*	Material slides Video explainer
12	Weight lifting: *polishing*	Material slides Video explainer Infographic
13	Traditional dance	Material slides Video explainer
14	Modern dance	Material slides Video explainer
15	Fighting scene	Material slides Video explainer
16	Final exam	Material slides Assessment tools

Implement

The last phase was getting everything developed to be integrated into the SIPEJAR Learning Management System (LMS) so the students can access them online. This includes uploading everything from teaching modules to presentation slides, explainer videos, infographics, motion graphics, and assessment tools. With it being like Moodle, the instructors can easily manage the content by creating meeting categories, then uploading files and organizing content release schedules.

All learning materials are organized according to weekly sessions, enabling students to follow a clear learning pathway, both in synchronous and asynchronous formats. Additionally, instructors can utilize the discussion forum feature for two-way interactions and provide regular feedback. With well-structured content in SIPEJAR, the learning process becomes more organized and flexible, allowing students to engage in independent study while staying connected with instructors and peers.

Evaluate

During the evaluation stage, a trial implementation of the developed product was conducted to assess the effectiveness of the 3D Animation: Body Mechanic learning process. This evaluation involved simulation-based learning during the 7th and 8th meetings to observe students' responses to the learning materials, media, and methods.

The pre-test involved directing the students in an undertaking where they created a jumping character animation. A minimum of instruction was given at the start for the students' blocking animation exercise. In case of trouble, the students should research these solutions independently through any source. This group had not received feedback from instructors or their peers, and it worked alone without any further learning media or support from the instructor.

In the post-test phase, students received in-class guidance about making jumping character animations and were required to practice blocking techniques directly. Throughout this process, students received immediate feedback from the instructor, correcting errors and deepening their understanding of animation techniques. Afterward, the students formed small study groups to continue the polishing stage independently outside the class. They're going to base their learning on the learning media developed in this research.

In the 8th meeting, both pre-test and post-test were conducted using a skills-based evaluation format. The students created a body mechanics animation based on the provided example, with the option to add improvisational movements. This activity was completed within a limited time frame (4 instructional hours) and conducted directly in the class. The outcomes of this trial were documented and presented in the accompanying visuals (not shown here). The findings highlight the impact of structured feedback and guided learning media on improving students' technical skills and comprehension in body mechanics animation.

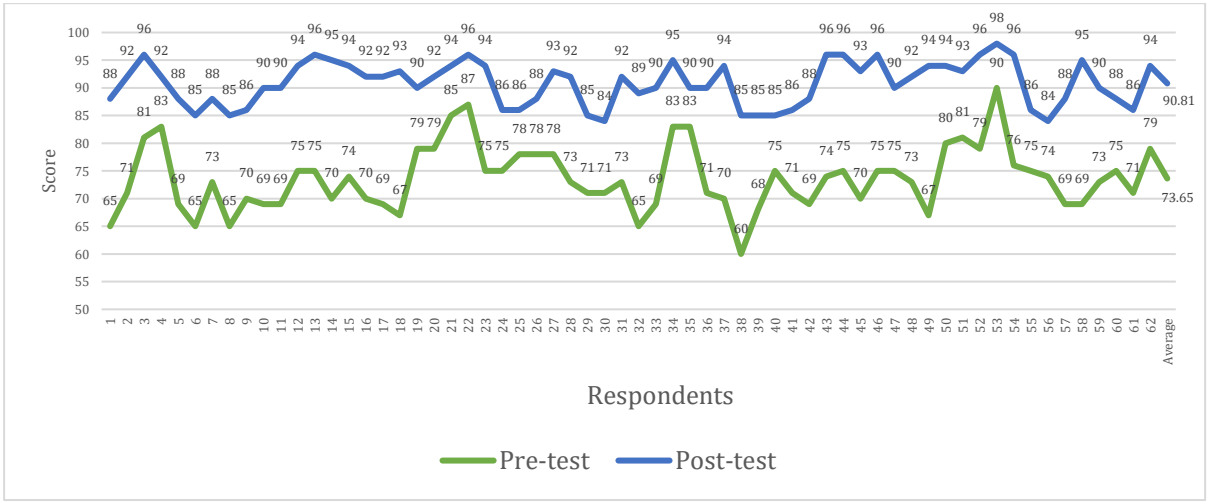

Figure 4. Comparison of pre-test and post-test result

Figure 4 reveals that the average pre-test score was 73.65, while the average post-test score increased to 90.81, reflecting an average improvement of 17.16 points or approximately 23.3%. Nearly all students boosted their scores, with some showing substantial improvement. For

instance, student #1 raised their score from 65 to 88, a gain of 23 points. However, a few students showed lower improvement, such as student #29 (Pre-test: 71, Post-test: 85), with an increase of 14 points.

Despite this, the post-test scores showed good consistency, with most students scoring above 85 and the lowest score being 84, achieved by two students. This indicates that the learning process successfully delivered the concepts of 3D animation effectively to most students. However, students with lower pre-test scores tended to remain in the lower range of post-test scores, even though they experienced improvement.

To assess the impact of the developed learning media on student performance, the researchers also conducted an analysis using Cohen's d method, which measures the standardized mean difference, the Formula 1 and 2, described by Hess & Kromrey (2004).

$$d = (M_1 - M_2) / SD_{pooled} \quad [1]$$

- M_1 = mean/average of post-test (90.81)
- M_2 = mean/average of pre-test (73.65)
- SD_{pooled} is the combined standard deviation of both groups, calculated using the formula 2.

$$SD_{pooled} = \sqrt{(n_1\text{-}1)SD_1^2 + (n_2\text{-}1)SD_2^2 / n_1 + n_2 - 2} \quad [2]$$

- n_1, n_2 = data amount (62 students)
- SD_1, SD_2 is the standard deviation of the pre-test and post-test calculated using the Microsoft Excel application with the formula *=STDEV('value 1':'value 62')*
- SD_1 = 5.8
- SD_2 = 3.9
- Sd_{pooled} = 4.96
- So, the Cohen's d value is 3.46

The calculated d value of 3.46 indicates an enormous effect size, suggesting a significant improvement in students' scores after participating in the 3D Animation: Body Mechanic course. This finding proved that the developed instruction media coupled with the collaborative project learning model indeed contributed to improved students' learning outcomes.

DISCUSSION

Based on the research findings, the body mechanics in 3D animation learning raised some primary issues among students, such as hardware-software mismatch, software mismatching versions, and language barriers due to tutorials delivered in a foreign language. All these findings have been reiterated by Karadoğan & Karadoğan (2019), who pointed out a significant emphasis on high-performance devices and the synchronized version of the software as critical in simulation-based learning. Therefore, it is essential to ensure that campus software versions to those of tutorials are similar to avoid student confusion while learning.

Language barriers, however, have been emphasized by Cervera (2024) who urbanised the importance of developing learning materials in the language of the local context for better students' understanding and engagement in technology-based learning. This has proven successful with the learning materials in Indonesian housed in LMS SIPEJAR because of its easier access and reduced dependence on foreign language tutorials. Similarly, Waskito et al. (2024) found differences between foreign tutorials and campus software, which frequently creates confusion in applying animation techniques. Therefore, software synchronization and platforms

such as Blender that are lightweight and compatible with low-specification devices greatly support effective learning.

This research also highlighted the big problems shown by the actual practice of being in online learning in practice courses. As proposed by Low et al. (2023), constant assessment and personal contact with instructors make the most indirect strategic efforts for students' minds to understand hands-on learning. It has a practical impact on learning, especially with learning strategies combining asynchronous online learning through LMS SIPEJAR and face-to-face feedback sessions that will allow students to study independently with their real-time guide in 3D animation.

The trial of learning mediabased on the SIPEJAR platform has proven to be quite effective in improving student outcomes for the 3-D Animation: Body Mechanic course. From an average score of 73.65, the pre-test average increased to 90.81 in the post-test, which means an average improvement of 17.16 points or about 23.3%. Analysis revealed that the team-based project learning model, supported by digital learning media, played a significant role in achieving this result. The resulting Cohen's d value of 3.46 proves that this effect size is "very large" (Cohen, 1988), providing strong evidence that this media largely elevates skills in students.

The effectiveness of this medium of learning could be seen through Vygotsky's social constructivism theory (1978), which states that learning is more effective when done with others. Students interact with each other sharing ideas, providing feedback, and working on assignments that are relevant to real contexts. This came in the form of a team-based project model where students teamed up to present animation projects, and teamwork paid off when students shared skills and improved understanding through discussion. This direct interaction with instructors also reinforces this theory regarding much-needed scaffolding (temporary guidance) that ensures adequate grasping of dense concepts by the students at times.

In addition to this is project-based learning, which matches the experiential learning theory as postulated by Kolb in 1984. This theory contends that involvement in real tasks such as blocking and polishing an animation achieves the most effective learning. Another supporting evidence for that is the very close applicability of the learning media. Blender was adopted as a lightweight, open-source software that is easily compatible with students' hardware so that there were few technical hindrances and they could better concentrate on their creative process. This aligns with Daft and Lengel's media richness theory (1986), which states that appropriate and supportive media are more effective in conveying complex information, such as 3D animation production. Moreover, learning materials in Indonesian contributed to the success, consistent with Mayer's multimedia learning theory (2005), which emphasizes that simple yet informative language and visuals enhance cognition.

Despite these positive results, some limitations were identified. For instance, students with lower pre-test scores tended to remain in the lower range of post-test scores, even though they indicated improvements. This highlights the need for a differentiated learning approach, consistent with Vygotsky's zone of proximal development (ZPD), where students with lower initial abilities require more intensive support to reach their full potential. Additionally, the reliance on instructor feedback underscores the importance of strengthening peer feedback, which, according to Wenger's communities of practice theory (1998), fosters learning through group discussion and observation.

Overall, this study demonstrates that the SIPEJAR-based learning media, supported by the team-based project model, significantly enhances students' skills in 3D animation. The combination of relevant media, direct interaction with instructors, and collaborative group work contributed substantially to the success of this learning approach. More forward-oriented may be

developed differentiated learning modules and further strengthened group work systems, which might maximize the potential of all the learners.

CONCLUSION

The present study has brought out many challenges that the students faced in the 3D Animation: Body Mechanic course at Universitas Negeri Malang. Mentionable challenges are hardware limitations, incompatibility in software versions between tutorial materials and campus devices, and language barriers in foreign tutorials. The student also faces many difficulties concerning independence in learning due to a lack of sufficient guidance and evaluation. Therefore, the study was to design project-based learning media using a team-based project approach integrated into the SIPEJAR LMS. The media involved video tutorials in Indonesia, infographics, and simpler character models to promote more flexible independent learning. The evaluation results showed that teamwork activity-based media highly and consistently improved learning outcomes which are highly reliabled teaching modes in the development of 3D animation competencies within higher education.

However, it unveils that students with low initial scores also showed low scores in the post-test. The findings demonstrate that there can be improvements with lower initial scores. This brings an argument for differentiated learning to be more intensive for those requiring additional support. Also, there is a need to emphasise strengthening peer feedback mechanisms since students need to be able to work more independently and collaboratively toward group projects as these tend to rely more on feedback from the instructor.

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Author contributions

The authors made significant contributions to the study's conception and design. The authors were in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

Conflict of interest

The authors declare that there is no potential conflict of interest.

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