Review Article

Enhancing Student Engagement in Physiology Education through Flipped Classrooms, Gamification, and Visualization: A Narrative Review

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Abstract

Background: Learning physiology is a crucial aspect of medical education, focusing on the study of normal human body functions as the fundamental knowledge required for every physician. However, studying physiology poses significant challenges, including the need for active learning, loss of motivation, and lack of student engagement.

Objectives: This study explores the impact of flipped classrooms, gamification, and visualization teaching methods on student engagement in physiology education.

Methods: This review integrates insights from studies published between 2020 and 2024, highlights the complementary strengths of these methods, and offers a roadmap for educators to create dynamic and engaging learning environments tailored to modern medical education.

Results: Nine published articles were included to provide an understanding of modern methods and their impact. The flipped classroom approach is a strategy to encourage active learning, but it can also increase students' workload. Incorporating game elements into the learning process can create a more enjoyable environment and enhance students' motivation to learn. Physiology is a complex subject with abstract concepts; therefore, visualization methods can simplify these concepts and ultimately support students' learning processes.

Conclusion: No single superior teaching or learning method is available. Educators and students must adapt their approaches to suit the specific needs of the classes and individuals.

Keywords: Flipped Classroom; Gamification; Physiology Education; Student Engagement; Visualization

Background

Medical education is a challenging path toward becoming a doctor (1). During this process, medical students are required to be lifelong learners and continuously update their knowledge (2). According to the Cambridge Dictionary, learning involves knowledge acquisition (3). Bloom's taxonomy divides learning into six levels, starting from the lowest: remembering, understanding, applying, analyzing, evaluating, and creating (4). The higher the level of Bloom's taxonomy, the more proficient a person is at mastering the subject (5).

Physiology is a complex but essential branch of knowledge in the medical field. Physiology studies the normal functions of living organisms, including their parts and all the biological processes occurring within them (6). Previous studies have demonstrated that physiology is often considered difficult to understand (7). Medical students need active engagement in the learning process to master the basics of physiology effectively (8).

Student engagement refers to the attention and effort devoted to learning performance and reflects the motivation to learn (9). Previous studies have revealed a significant relationship between student engagement

and learning outcomes (6, 10, 11). Factors that influence student engagement in learning include active participation in class, the relationship between teachers and students, active and collaborative learning, and a conducive educational environment (6).

Despite the growing awareness of its significance, strategies to enhance student engagement in physiology education are inconsistent and often inadequately evaluated. Therefore, conducting a well-designed study in this area is crucial for generating reliable evidence for constructive andragogical approaches. Rigorous research is essential to ensure that interventions address the barriers students face, leading to optimal learning outcomes and efficient educational resources. A carefully structured study helps identify gaps in existing methods and fosters the development of innovative approaches. Without such evidence, efforts to improve engagement may remain fragmented, unsystematic, and less impactful.

Objectives

Several teaching methods can enhance student engagement. This review explores the relationship between flipped classrooms, gamification, and visualization teaching methods and student engagement in human physiology education. It synthesizes the existing research and compares the most efficacious teaching methods for enhancing student participation and understanding in human physiology courses.

Methods

This narrative review was conducted to synthesize recent evidence on strategies to enhance student engagement in physiology education. Literature search was performed in PubMed and Google Scholar using the following keywords: "*student engagement,*" "*study method,*" and "*physiology.*" Boolean operators were applied (e.g., "*student engagement*" AND "*study method*" AND "*physiology*"), with filters set for publication period (2020-2024) and language (English).

PubMed was selected because it provides comprehensive biomedical coverage, and Google Scholar was included to capture additional peer-reviewed educational studies. Other databases, such as Scopus, Web of Science, and ERIC, were not prioritized because of their substantial overlap with records retrieved from PubMed and Google Scholar, as well as subscription limitations. For the scope of this narrative review, the combination of PubMed and Google Scholar was considered adequate for identifying the most relevant studies, resulting in the inclusion of nine articles in the final synthesis.

The selection process comprised two stages: (1) screening titles and abstracts to remove duplicates and irrelevant articles; (2) full-text review of potentially eligible studies. Two reviewers independently conducted the screening and data extraction. Discrepancies were resolved through discussion until a consensus was reached.

The data were extracted and reviewed for each article. The inclusion criteria were as follows: (1) original research published in peer-reviewed international journals, (2) written in English, and (3) explicitly examining student engagement in physiology education. The exclusion criteria were as follows: (1) reviews, conference abstracts, editorials, and studies not directly related to physiology or student engagement; (2) not written in English; and (3) full text not available.

The initial search identified 543 and 345 articles in PubMed and Google Scholar, respectively. After removing duplicates and irrelevant records, 38 articles remained for full-text review. Of these, nine met the inclusion criteria and were included in the final synthesis. Although the number of included studies was relatively small, it reflects a limited but emerging body of literature that focuses on student engagement strategies in physiology education. The overall study selection process is illustrated in Figure 1.

Data were extracted using a structured matrix that included the study design, participants, teaching methods, and key findings. The synthesis followed a thematic narrative approach, grouping the results into three main categories: the flipped classroom, gamification, and visualization. This review did not follow a systematic review protocol, such as PRISMA, as the aim was to provide a broad narrative overview of recent trends rather than a systematic assessment.

Results

Nine studies were included in this narrative review. Table 1 summarizes the articles examined in this review. Each row in the table represents an individual study, detailing its methodology, population, and key findings. This overview enables readers to swiftly grasp the diversity of approaches explored in the literature and their specific impacts on student engagement in physiology education. Lu et al. (2023) asked whether a flipped classroom would improve exam performance compared with traditional teacher-centered lectures.

Their findings confirmed that students in the flipped classroom achieved significantly higher usual performance and final exam scores, directly answering the study question (12). Similarly, Ganfornina et al. (2023) investigated whether flipped classrooms could

enhance intrinsic motivation and learning outcomes in neurophysiology. The results showed higher final grades and improved learning perceptions, supporting the effectiveness of this approach (13). Anderson et al. (2023) explored whether the different delivery modes (online, hybrid, and in-person) of flipped teaching during the COVID-19 pandemic affected performance. Interestingly, hybrid flipped formats were linked to lower exam scores—while the flipped model can be beneficial, contextual factors such as modality and external stressors are crucial (14).

Hennekes et al. (2021) investigated whether incorporating the PEGASUS Games into preclinical education enhanced outcomes in anatomy and physiology. Their results confirmed that students exposed to the game showed superior learning performance (15). Roberts et al. (2024) asked whether a board game ("Codenames") could increase engagement and higher-order thinking in physiology classes. The findings revealed that this gamified activity promoted active involvement and encouraged integrative thinking, addressing the study's central question (16). Bawazeer et al. (2023) evaluated whether interactive polls (Kahoot, Mentimeter, Blackboard) could sustain engagement during a pandemic. This study demonstrated a positive effect, showing that digital gamified polling created an enjoyable learning atmosphere and enhanced interaction (17).

Subbiramaniyan et al. (2021) explored whether memes could improve the engagement and comprehension of renal physiology. Their study confirmed that memes increased enjoyment and simplified complex topics, directly answering the research question (18). Su et al. (2023) investigated the effectiveness of the "Hand as Foot" method as a visual analogy for physiology education. A randomized trial demonstrated that this technique significantly improved understanding and engagement, validating the research aim (19).

Keba et al. (2024) assessed whether word clouds generated via Mentimeter could serve as a formative assessment and engagement tool. The results showed that this technique effectively monitored the learning progress while enhancing classroom participation (20), answering the study question.

Conventional lectures are teacher-centered and often limit student interaction and long-term retention. The flipped classroom shifts the focus to active, student-centered learning with pre-class preparation and in-class discussions, resulting in improved understanding and problem-solving, but may increase student workload. Gamification stands out for transforming learning into enjoyable and motivating experiences through elements such as games and competitions, fostering engagement, autonomy, and positive emotions. Visualization methods, including memes, hand gestures, and creative digital tools, simplify complex physiological concepts, making learning more accessible and memorable. The flipped classroom, in combination with gamification and visualization techniques, has emerged as the most efficacious approach. It offers the deepest engagement, enhanced learning motivation, and better retention, as it is well-structured and tailored to student needs.

This review addresses three study questions concerning flipped classrooms, gamification, and visualization in physiology education. Flipped classrooms have been shown to enhance engagement and learning outcomes by fostering active, student-centered participation, with most studies reporting higher exam scores and more positive learning perceptions than traditional lectures. Nevertheless, outcomes could vary depending on the delivery modality. Gamification methods, including serious games, board games, and interactive digital polls, consistently increase student motivation, enjoyment, and higher-order thinking, confirming their value in sustaining participation. Visualization techniques, such as memes, hand gestures, and word clouds, effectively simplify complex physiological concepts and promote comprehension while maintaining student interest. Overall, the evidence indicates that all three methods improve engagement in different but complementary ways. In particular, flipped classrooms, in combination with gamification and visualization, have been considered the most comprehensive approach for enhancing participation and understanding in human physiology courses.

Discussion

Physiology requires students to possess an understanding beyond mere memorization (21, 22). Students must integrate complex concepts to develop a strong scientific foundation. Mastering physiology is a crucial bridge connecting preclinical and clinical learning in medicine. Fatima et al. present several challenges and obstacles in studying physiology, including concept integration (84%), the use of active learning methods (81.7%), and the role of educators in answering student questions (88.4%) (23). Challenges in studying physiology can be addressed through

engagement and the active involvement of students in learning (24).

Educators and students must contribute toward fostering student engagement (9). Reinke et al. state that educators are responsible for creating learning environments and experiences that promote active learning and facilitate social interaction in the classroom (6). Educators must package learning such that students develop interest and spend more time studying. Conventional teaching methods that emphasize teacher-centered lectures are no longer relevant to the evolving needs of university students (25). Conventional learning, which limits the interactions between students and teachers and among students (26), must be replaced with other teaching methods that enhance student engagement.

The flipped classroom is a student-centered learning method that has been proven to increase student engagement (27, 28). In its implementation, students must prepare themselves before class begins by reading materials or watching prerecorded videos (29). Learning instructions are provided to the students before the class starts. During in-class meetings, the learning process focuses on group discussions, case-based studies, debates, and short presentations (13). Hadad et al. (2025) substantiate the significant decay of physiological knowledge over time, demonstrating the most significant loss in the gastrointestinal system while noting a positive retention only in endocrinology among fourth-year students. These findings underscore the critical necessity of implementing active learning strategies—the flipped classroom, gamification, and visualization methods—as they are directly focused on reinforcing long-term memory and counteracting the Ebbinghaus forgetting curve (30). Lu et al. investigated the impact of the flipped classroom on physiology education. This study was conducted with 131 respondents divided into six classes and randomly assigned to receive conventional and flipped classroom instruction. The findings showed a significant difference in final exam scores between the groups, with the flipped classroom outperforming the conventional teaching class (p <0.05). The number of students in the flipped classroom group who failed the final exam was also lower than in the conventional group. Notably, 77.58% of the respondents agreed that the flipped classroom improved their understanding, 86.21% mentioned that it enhanced their independent learning skills, and 70% stated that it improved their problem-solving skills (12).

Interactive activities built into the teaching and learning processes are created because time is allocated for students to be first exposed to new concepts and materials. The flipped classroom promotes active, cooperative, collaborative, and problem-based learning (12). Existing research has proven that flipped classrooms are beneficial for increasing student engagement (12, 29, 31). However, despite its many advantages, the flipped classroom may add to the burden and cause some students to feel overly anxious and lose motivation to study because of the limited pre-class independent study time (12, 13).

Ganfornina et al. attempted to address the increased workload arising from the flipped classroom learning method by eliminating pre- and in-class assessments (13). This approach emphasizes the students' internal motivations for learning. Ganfornina et al. investigated the application of the flipped classroom in neurophysiology education. Neurophysiology content was delivered at the end of the physiology curriculum and is a challenging subject. This study compared the final grades of groups that received traditional and flipped classroom instruction. Printed student workbooks and study guides were provided before class began. During the class sessions, the instructor implemented doubt-solving activities, group discussions, debates on important topics, and brief presentations linking the learning material to clinical aspects. The classes concluded with challenge questions and take-home messages. The results showed that the group taught using the flipped classroom method demonstrated better memory retention (p < 0.009). Additionally, the flipped classroom approach was helpful in understanding crucial neurophysiological concepts (p = 0.048). The students in the flipped classroom group achieved higher exam scores (13).

Students in large classes are more likely to skip sessions and focus solely on studying for exams (32). This habit drives students to adopt a test-oriented learning approach, ultimately leading to poor long-term material retention. The flipped classroom teaching method offers a solution by fostering active learning, which promotes the longer retention of information in the brain (33). According to Ganfornina et al., there is no universally perfect teaching or learning method; each student must identify the approach that best aligns with their intrinsic motivation (13). It also highlights the importance of educators preparing concise, effective, and practical materials to ensure that the flipped classroom model is accessible and beneficial to all students, including those hesitant to embrace this teaching method (13).

Anderson et al. examined the impact of using a hybrid flipped classroom model during the covid-19 pandemic and found that it decreased academic performance compared to groups attending either entirely in-person or fully online classes (14). Students perceived the hybrid flipped classroom to offer no significant advantages over traditional teaching methods. In-class sessions emphasize active learning by engaging in group discussions and problem-solving activities. However, some students reported discomfort with active learning because of the uncertainty of correct answers, even though the instructors ultimately clarified this. The hybrid format also limited the instructors' ability to effectively evaluate small-group discussions, and the mixed presence of in-person and online participants further reduced the effectiveness of the flipped classroom approach. Despite these challenges, some students recognized that active learning improved their critical thinking skills (14).

Gamification is a teaching method that leverages the fun of playing and connects it with the learning process. This approach can make the learning environment enjoyable and ultimately increase students' attention. In addition to the learning environment, enhancing student engagement requires attention to active learning, social interaction in learning, and collaboration. Traditional classes deliver materials to one or several separate classes, causing students to struggle integrating the overall material. Gamification can help students integrate materials and create fun learning environments, ultimately sparking active learning.

The benefits of gamification in education, as researched by Waluyo et al., include the addition of game elements such as points, badges, and goals, which create a positive learning environment and foster positive emotions (34). This approach has been shown to reduce anxiety and increase student motivation to learn (34). A pleasant learning atmosphere encourages students to participate actively in the learning process (35). Additionally, gamification fosters autonomy, competence, and relatedness, contributing to intrinsic and extrinsic motivation, as seen in tools such as Kahoot and Quizlet. Gamification's ability to create enjoyable and engaging environments has consistently been linked to improved student performance and participation (35, 36).

Hennekes et al. conducted a study comparing learning outcomes between groups taught using gamification and those taught using conventional methods in the context of neck and thyroid education. The gamified group engaged in three different games: "ball toss," "taboo," and "pin the tail," all played in groups with the objective of helping students retrieve information from their memory. The non-gamified group received traditional instructions. The results showed that the gamified group achieved higher immediate post-test scores, increased learning motivation, and improved social interactions (15).

Roberts et al. presented data on the use of games in physiology education. Seventy-four respondents were divided into small groups and allowed to play the educational games. The games used in this study were designed to achieve higher levels of Bloom's taxonomy through interleaving, recall, and teamwork. Respondents stated that using games gave them a new perspective on learning, made them more interested, and enabled them to integrate the topics they studied (16). Gamification has the potential to increase student engagement in physiology teaching. An increase in student engagement primarily occurs through the creation of a fun learning environment. However, educators must design games that enhance students' analytical and evaluative skills to reach higher levels of Bloom's taxonomy. Designing games must be tailored to various aspects, including the characteristics of the students, while considering the type of game player (37).

Classroom interactions are important for enhancing student engagement. The interaction between students and instructors in conventional classrooms during Q&A sessions is sometimes not optimal because students tend to be shy about asking questions and fear making mistakes in front of their peers. An alternative for fostering this interaction is online polling. Applications, such as Kahoot and Mentimeter can be used to increase student engagement. Research conducted at King Saud bin Abdulaziz University during the COVID-19 pandemic revealed the benefits of online polling in increasing engagement among physiology students. Online polling can facilitate interactions between educators and students. Most respondents agreed that they were comfortable using online polling services.

Additionally, online polling improved grades, and 88.9% of the respondents agreed to use online polling again, even for other subjects. The increase in grades observed in previous research may be relevant to retrieval theory. A retrieval technique is one way to achieve deep learning by first attempting to recall materials without referring to other sources. Retrieval is an active learning strategy (17).

Using creative learning media allows for longer retention of new knowledge in the brain. Memes are a means of communication that combine elements of pop

culture, and are usually used for online conversations. Using media, such as memes, creates a combination of enjoyable textual and visual materials (38-40). Making memes requires analyzing and integrating material, which is beneficial for achieving higher levels of Bloom's taxonomy (41). The benefits of memes in increasing student engagement in physiology education have been observed in a study by Subbiramaniyan et al. This study involved 146 students studying renal physiology who created a meme. A total of 44% of students stated that using memes was enjoyable and could relieve stress. Notably, 38% of the students felt that memes made information easier to remember than conventional text forms. Thirty% of students stated that memes could simplify complex concepts and make the material easier to understand (18).

Learning media are not limited to presentation slides, textbooks, or two-dimensional images. Conventional learning media lack the ability to visualize materials. Using virtual reality (VR), augmented reality (AR), or mixed reality (MR) allows more visual teaching and helps students understand abstract concepts (42, 43). However, the use of advanced technology incurs significant costs and is not available in all areas. Intelligent visualization alternatives use hand gestures. Hand-as-foot is a teaching method that uses hand gestures to simulate anatomical structures and functions. Using hands-in visualization can help students understand complex physiology. A randomized study by Su and Zhao examined the effect of the Hand as Foot on physiology education. Eighty-four respondents were divided into two groups: traditional and experimental. Renal physiology was studied in both groups. The results showed that the group taught using the hand-as-the-foot method had higher engagement levels, better understanding, and better recall than the conventional group (19).

The hand as a foot can increase student engagement. This aligns with the method's ability to create a conducive learning environment. Educators practice hand gestures while delivering material, followed by students, initiating active student engagement and fostering interactions between teachers and students. Another benefit of the hand as a foot-teaching method is the simplification of complex materials, which increases students' learning motivation. However, Su and Zhao conducted their study on only one topic: renal physiology. Further research is required to determine whether the foot-teaching method can be applied to other physiological areas (19).

Evaluation is a critical aspect of the learning process and can be summative or formative. Quick assessments conducted after delivering the material, known as formative evaluations, help determine whether a class understands the presented content. Through formative evaluation, educators can adapt their teaching methods to be more relevant and aligned with student needs. Research by Keba et al. revealed that using word clouds with Mentimeter provides rapid visualization of students' understanding in class following lessons. This approach is an effective formative evaluation that offers valuable insights into enhancing learning processes (20).

A summary of this review is presented in Figure 2. The flipped classroom encourages active learning by combining independent studies with clear study guidance before class, such as reading materials or watching prerecorded instructional videos. Educators should focus on activities that develop problem-solving, discussion, and critical thinking skills during class rather than relying on traditional lectures. However, the increased workload associated with flipped classrooms can lead to a loss of motivation among students. Therefore, educators must be attentive to student conditions and design well-structured curricula. Combining gamification and visualization with the flipped classroom model can create a more enjoyable classroom atmosphere and enhance interactions between students, teachers, and peers. Learning activities packaged as games can evoke positive emotions and reduce student stress, which has a positive impact on increasing student engagement. Educators should also ensure that games are tailored to suit the characteristics of students, which creates a challenge in designing meaningful games. Visualization methods like "hand as foot" or memes can simplify complex and abstract material, making it easier for students to understand. Every learning process should be evaluated to create a dynamic learning environment that meets the needs of the class. Tools such as word clouds can be used for formative assessment, providing quick visual feedback on students' understanding and helping educators refine their teaching strategies for better outcomes. These innovative methods are expected to improve student engagement by improving learning outcomes, increasing motivation, and attaining higher material retention. These innovative methods are expected to enhance student engagement by improving learning outcomes, increasing motivation, and promoting material retention. Nonetheless, this study has several limitations. First, the review included only a few studies (n = 9), which may

have restricted the generalizability of the findings. Second, the search strategy was limited to two databases and did not include ERIC, potentially leading to the omission of relevant studies. Third, there was considerable heterogeneity among the included studies in terms of the study design, population, and outcome measures, which may have affected the comparability of the results. Finally, a formal quality assessment of the primary studies was not conducted, which may have limited the ability to evaluate the strength of the evidence.

Conclusion

Physiology is challenging because of its complex concepts and the need for a deep understanding. The key to a student's success in mastering these complex concepts lies in active learning, which promotes the longer retention of information in the brain.

Modern teaching methods provide educators with diverse tools to address the varying learning styles and classroom dynamics. The integration of flipped classrooms, gamification, and visualization represents a shift toward more interactive and student-centered teaching approaches in physiology education. By leveraging these methods, educators can design adaptable strategies that align with the evolving demands of modern medical education, ensuring a more engaging and effective learning environment for students. Future research should involve larger multi-institutional studies and incorporate dedicated educational databases to enhance the generalizability of the findings. Additionally, direct comparisons among different innovative teaching methods are required to identify the most effective strategies for specific physiological topics and student cohorts.

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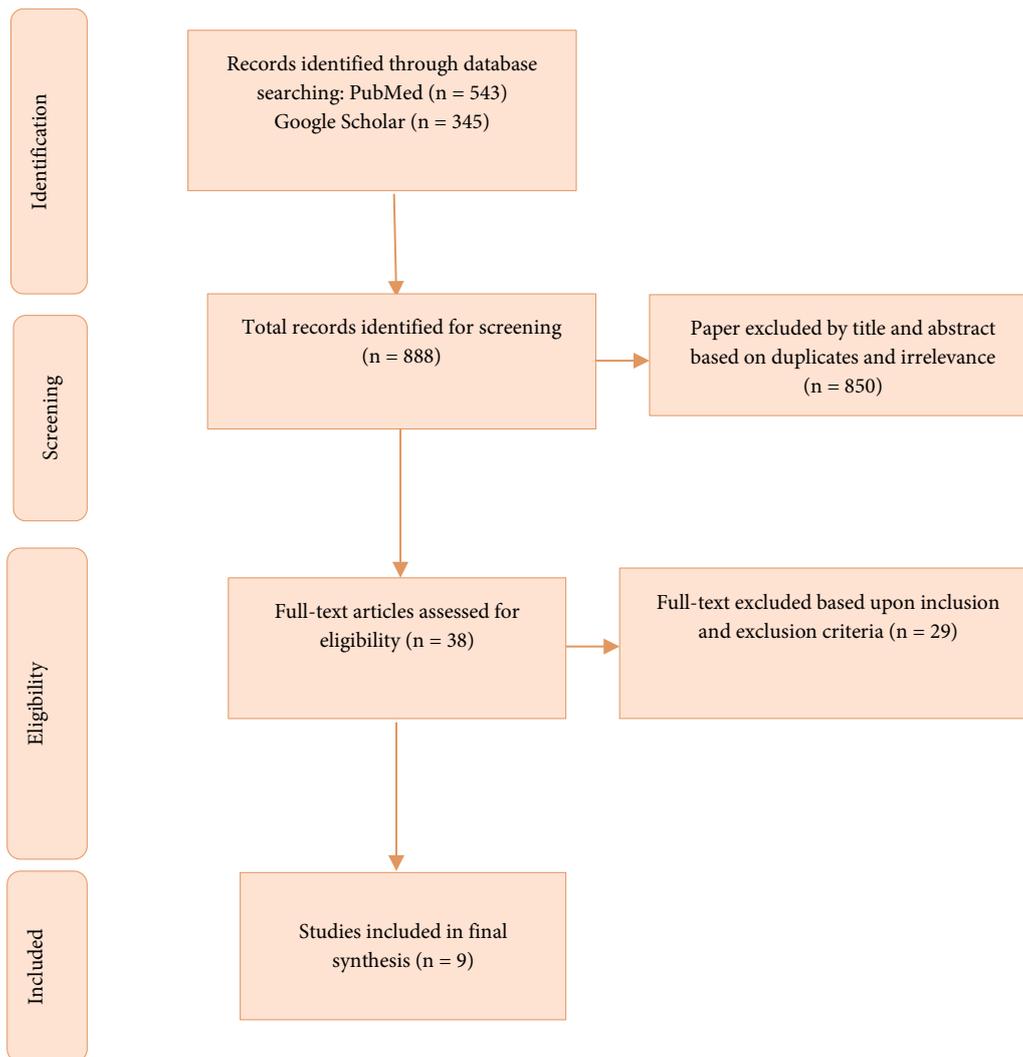
Figure 1. Flowchart of the study selection process showing the identification, screening, eligibility, and inclusion stages
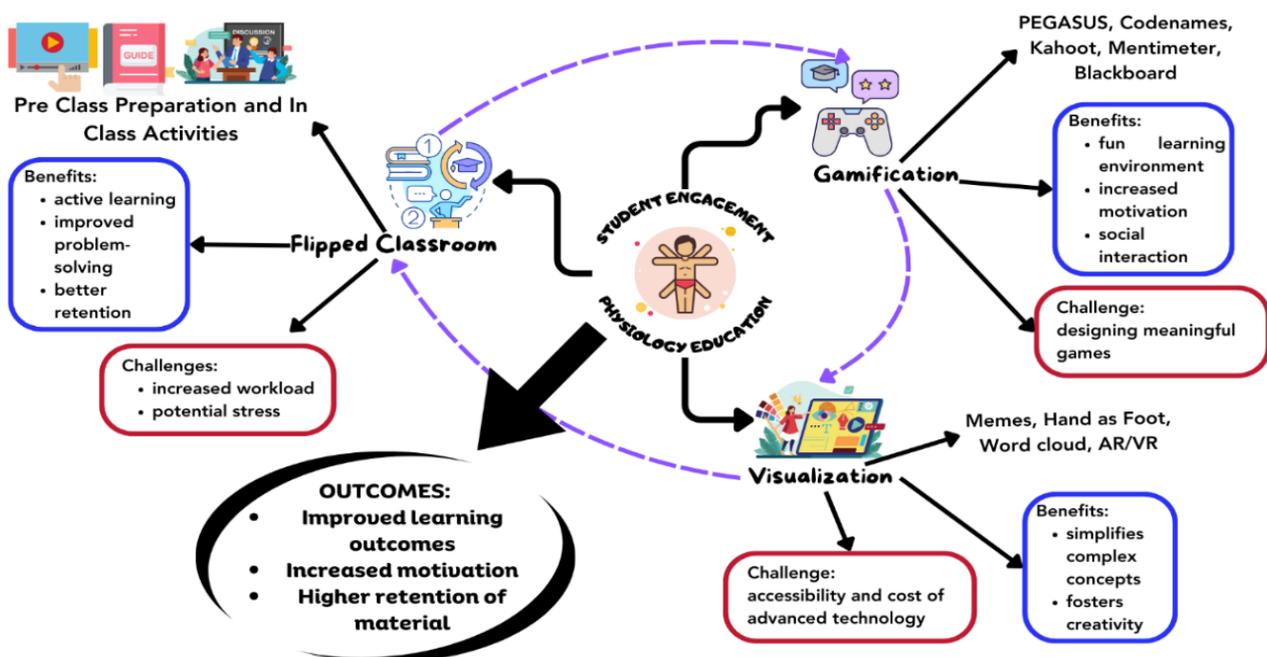

Figure 2. Student Engagement in Physiology Education from Different Teaching Methods and Their Outcomes

Table 1. Summary of Studies Included in This Review

Study Author (Year)	Method	Participants	Findings
Lu et al. (2023) (12)	Student-centered flipped classroom compared to traditional teaching class in physiology education	131 2nd year medical students	This research showed that students' usual performance and final exam scores in the flipped classroom were significantly higher than those in the traditional teaching class.
Ganfornina et al. (2023) (13)	Flipped classroom compared to standard teaching group in neurophysiology learning, focusing on students' intrinsic motivation and performance	891 (standard) vs. 962 (flipped) 2nd year medical students	This study compared the final grades between the standard teaching group and the flipped classroom group. The flipped classroom teaching method group reports a significant increase in final exam scores. Furthermore, flipped classrooms have shown a benefit in creating a positive perception and understanding.
Anderson et al. (2023) (14)	Flipped classroom during the COVID-19 pandemic in teaching Clinical Physiology 1 and 2. The lesson was delivered online, hybrid, or in person, and the exam scores were compared between groups.	45 2nd year medical students	Students who received a hybrid modality flipped classroom during the COVID-19 pandemic were associated with lower exam scores.
Hennekes et al. (2021) (15)	The PEGASUS Games (Physical Exam, Gross Anatomy, Physiology and UltraSound Games) for preclinical medical education	20 1st year medical students	This research compared the learning outcomes of the game group and the non-game group after learning neck and thyroid material. The game group showed better performance than the non-game group.
Bawazeer et al. (2023) (17)	A cross sectional study on students' engagement using interactive polls (Kahoot, Mentimeter, Blackboard) in teaching physiology, pathology, and pharmacology during COVID-19 Pandemic	184 3rd and 4th year medical students	This research demonstrates the impact of using interactive polls on increasing student engagement by creating an enjoyable learning atmosphere.
Roberts et al. (2024) (16)	Codenames board game for the physiology classroom, requiring, at minimum, a simple list of vocabulary terms	74 1st year medical students	The study's findings reveal that participating in this activity increased students' active involvement and encouraged them to engage in high-level integrative thinking, irrespective of their grade level.
Subbiramaniyan et al. (2021) (18)	A meme-based approach for enhancing student engagement and learning in renal physiology	280 2nd year medical students	This research indicates that memes can enhance student engagement by increasing enjoyment in learning and simplifying complex concepts.
Su et al. (2023) (19)	Effectiveness of the "Hand as Foot" teaching method using a randomized controlled trial in human physiology education	84 health management students	The "Hand as Foot" teaching method demonstrated strengths in engaging students and aiding comprehension.
Keba et al. (2024) (20)	Using Word Cloud with Mentimeter as a formative assessment classroom technique in physiology	150 1st year medical students	The word cloud provides formative evaluation and helps monitor student understanding in the classroom.