DOI: https://doi.org/10.70749/ijbr.v3i1.531

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://induspublishers.com/IJBR
ISSN: 2960-2793/ 2960-2807

Comparing Gamified and Traditional Approaches in Neuroanatomy Education: Effects on Academic Performance and Critical Thinking

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ARTICLE INFO

Keywords

Gamification, Critical Thinking, Medical Education, Academic Performance.

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Declaration

Author's Contributions: Ayesha Haque conceived, designed, and conducted the research, analyzed the data, and wrote the manuscript.

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History

Received: 03-10-2024
Revised: 23-12-2024
Accepted: 18-01-2025

ABSTRACT

Objective: To compare the academic scores and critical thinking disposition of undergraduate dental students taught through gamification and traditional methods. **Study Design:** A comparative prospective study. **Place and Duration of Study:** Department of Anatomy, HITEC-Institute of Medical Sciences, Dental College, Taxila, from September to November 2022. **Methodology:** Fifty-four first-year Bachelor of Dental Surgery (BDS) students were randomly assigned to a control group (Group A) and an experimental group (Group B). Group A participated in traditional small-group discussions following large group interactive sessions (LGISs), while Group B engaged in a gamified learning intervention ("Heads Up"). Each intervention consisted of eight sessions, with knowledge assessed through MCQs after each session and critical thinking disposition compared using the Yoon Critical Thinking Disposition Inventory (YCTDI) after the study. Post-intervention, the groups crossed over to validate results. Data were analyzed using SPSS version 27, with statistical significance set at $p \leq 0.05$. **Results:** Participants in Group B demonstrated significantly higher academic scores in MCQ-based tests compared to Group A ($p < 0.05$). Critical thinking disposition, particularly in the self-confidence subdimension, was also significantly higher in Group B (4.08 ± 0.88) compared to Group A (3.55 ± 0.86). **Conclusion:** Gamification is an effective, low-cost, and engaging strategy for teaching neuroanatomy, enhancing academic performance and critical thinking disposition among dental students.

INTRODUCTION

Gamification is an emerging tool in medical education, that is rapidly gaining popularity due to its potential to improve learning.[1,2] By incorporating game elements, this teaching methodology promotes peer cooperation and competition within an academic context.[3] Key benefits of gamification include the development of problem- solving skills, better knowledge retention, and promotion of autonomous learning in a safe and engaging environment.[4-7] Additionally, gamification encourages better communication, self-reflection and deep learning by targeting higher cognitive levels in accordance with Bloom's taxonomy.[8]

Neuroanatomy is considered as a challenging subject by medical students and is often associated with "neurophobia" a fear or aversion to neural sciences and clinical neurology.[9] Mastery in this field requires the ability to analyze, evaluate, and interpret complex concepts, which relies heavily on well-developed critical thinking. However, these skills are not easily cultivated and are influenced by cultural norms and teaching practices. A study reported that only 33.8% of medical students in Pakistan demonstrated critical thinking skills, compared to 78% in the United States, a disparity attributed to traditional teaching methods and cultural barriers that discourage inquiry and critical discussion. In medical education, innovative teaching methods are increasingly explored to motivate, engage, and develop students' critical thinking skills.[10] Investigating the role of gamification in developing critical thinking, particularly in localized educational contexts, could provide valuable insights for educators and policymakers.[11]

Despite empirical evidence supporting these advantages, the opinion about the effectiveness of gamification is divided, with some studies reporting negligible or no improvement in knowledge acquisition when compared to traditional teaching methods.[12-14] For instance, Lee et al found no significant knowledge gains among students exposed to game-based modules versus traditional PowerPoint-based didactic teaching. [13] Similarly, Jadoi et al documented a lack of its measurable impact on learning outcomes.[14] While gamification has been integrated into the curricula of some universities, the underlying mechanisms that drive its influence remain unclear, warranting further research.

In Pakistan, where traditional teaching strategies still dominate, gamification offers a promising approach to address these challenges. By leveraging Kolb's experiential learning model, gamification could help overcome cultural and pedagogical barriers, enhancing critical thinking and deep learning in neuroanatomy. However, the evidence supporting its efficacy remains inconclusive, necessitating further exploration.[12-14]

This study aims to address this gap by investigating the effects of game-based learning compared to traditional methods in teaching neuroanatomy to undergraduate dental students. By quantifying differences in academic performance and critical appraisal skills, this research seeks to evaluate the effectiveness of gamification as a low-cost, low-tech solution for teaching a historically complex subject in anatomy. The findings will provide valuable evidence for policymakers and educators, guiding future curricular reforms and teaching strategies.

METHODOLOGY

Study Design: This was a comparative prospective study conducted in the Department of Anatomy at HITEC-Institute of Medical Sciences, Dental College, from September to November 2022.

Inclusion Criteria: First-year Bachelor of Dental Surgery (BDS) students were included in the study. **Exclusion**

Criteria: Students who missed any sessions during the intervention were excluded from the study.

Sample: Participants were randomly assigned to a control group (Group A) and an experimental group (Group B) using simple random tables. The sample size calculation was performed using *G Power version 3.1.9.7* with an effect size (d) of 0.8 an alpha error probability of0.05 and Power (1-β) of 0.80. The calculated sample size was 52 participants, divided equally into two groups (26 each). However, to accommodate the class size of 54, the sample size was adjusted to 27 participants per group.

Ethical Approval: Approval for the study was obtained from the Institutional Review Board of the Institute (Ref: Dental/HITEC/IRC/35/10).

Intervention: Both groups were administered a pre-intervention test (YCTDI) at the start of the intervention to assess baseline critical thinking disposition. The intervention consisted of eight large group interactive sessions (LGISs), each lasting one hour. The LGIS was followed by small group discussion session for control group A and game-based session (heads-up) for group B, on the following two days.

The participants in Group B were divided into two teams, with each team participating in two rounds of a game during the post-LGIS session.

The game design, “Heads Up,” was adapted from the “Neurological Hat Game” by Garcin et al.[15] Each session involved the use of a deck of 100 cards featuring symptoms, signs, investigations, and diagnoses related to neurological conditions. Cards were reviewed by two subject experts to ensure accuracy.

In the first round, a team member (the "Guesser") from Team 1 held a card above their head and attempted to guess the word written on it based on one-word verbal clues provided by their teammates (the "Clue Givers"). The Guesser had two minutes to guess as many cards as possible for their team. Once the time was up, a member from the opposing team (Team 2) took their turn. This process continued, with all team members taking turns as the Guesser, until all cards had been used.

In the second round, the same set of cards was used, but team members had to provide clues through miming rather than verbal hints. Throughout the game, teams could track their performance using a leaderboard.

At the end of the game, participants engaged in a discussion about each card. The entire session lasted two hours, with the final 30 minutes dedicated to debriefing and discussion.

Instructors and syllabus remained same for both groups. Each post LGIS session was followed by an MCQ based test to compare knowledge of both groups. At the end of intervention, post-Intervention (YCTDI) was administered to assess any difference of critical disposition between two groups.

After the intervention, the groups were crossed over. Group A was taught spinal tract anatomy using small group discussions, while Group B learned through gamification over the next eight sessions, conducted using the same format.

Parameters

Academic Achievement: Multiple-choice questions (MCQs) based on Bloom’s taxonomy were used to compare gain of knowledge between two groups. The MCQs evaluated knowledge, comprehension, application, and analysis of cranial nerves anatomy. A total of 25 MCQs for each session were developed following the methodology described by Thompson et al.[16]

Critical Thinking Disposition: Yoon Critical Thinking Disposition Inventory (YCTDI) was used to measure this parameter.[17] This 27-item validated instrument evaluates seven subscales including Prudence, Intellectual Curiosity, Confidence, Systematicity, Intellectual Fairness, Skepticism and Objectivity. Higher scores indicate greater critical thinking disposition. The instrument has been validated for health professionals (Cronbach's α = 0.84) and has been employed in similar studies.[17] Post-intervention scores were used to compare difference in critical thinking disposition of two groups.

Data Analysis

Data were analyzed using SPSS version 27.0. Mean differences in academic scores and critical thinking disposition factors were compared between the two groups. A paired sample t-test was used to analyze post-intervention mean scores of different subdimensions, with a significance level of $p \leq 0.05$.

RESULTS

The study included a total of 54 participants, comprising 8 males (15%) and 46 females (85%). Participants were evenly divided between the experimental group B and control group A, with 27 in each. There ages ranged between 19-22 years of age.

The results indicate that the mean academic scores in Group B, which was exposed to game-based learning, were significantly higher across five post-session exams compared to Group A (Table- 1).

Table 1

Comparison of academic scores between group A (Exposed to traditional methods) and group B (exposed to gamification)

Post Session Exam number	Group A (n= 27)	Group B (n= 27)	p-value
	Mean Scores ± SD (Total marks=25)		
1	18.5± 2.17	19.52±2.18	0.10
2	18.65± 1.32	19.2± 2.56	0.34
3	18.26± 1.45	19.32± 2.28	0.05*
4	17.65± 1.62	18.8 ±2.91	0.08
5	18.03± 2.42	19.36 ± 2.11	0.04*
6	16.65± 2.31	19.04 ± 2.07	0.001**
7	17± 1.81	18.72 ± 1.62	0.001**
8	17.07±2.05	19.44 ± 2.25	0.001**

There was no difference of critical thinking disposition between group A and B based on the results of pre-intervention YCTDI (Mean ± SD Group A =81.04 ± 2.24 Group B= 80.90 ± 2.40 *p* = 0.96). However, the results of post-intervention YCTDI indicate that mean critical thinking disposition in the subdimension of self-confidence was significantly higher in Group B (4.08 ± 0.88) compared to Group A (3.55 ± 0.86) (Table-2) (Figure-1).

Figure 1

Post Intervention Comparison of Critical Thinking Disposition among the Participants of Group A and Group B.

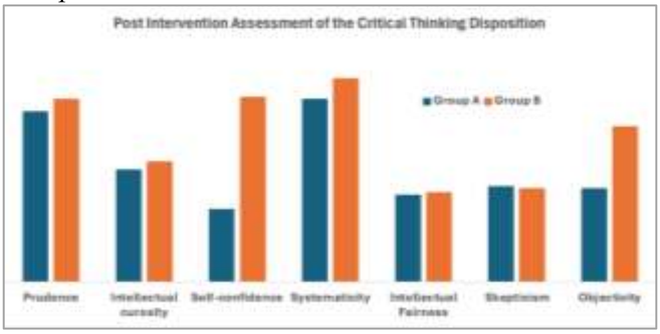
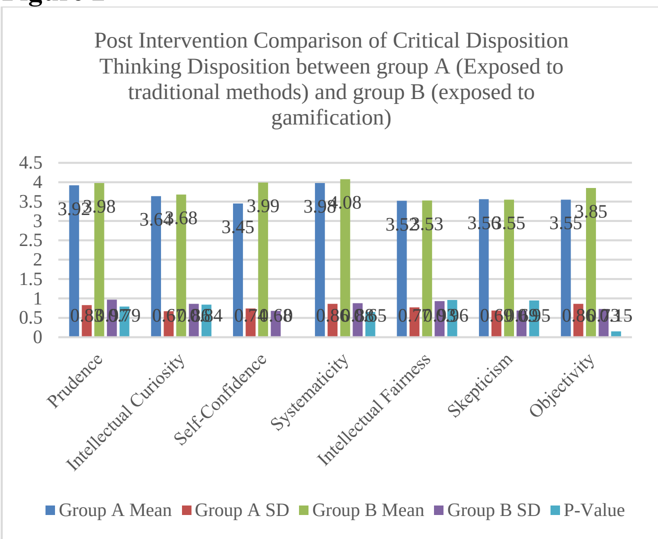


Table 2

Post Intervention Comparison of Critical Disposition Thinking Disposition between group A (Exposed to traditional methods) and group B (exposed to gamification)

Yoon's Critical Thinking Disposition Inventory Subdimensions	Group A	Group B	P-Value
	Mean± SD		
Prudence	3.92±0.83	3.98±0.97	0.79
Intellectual Curiosity	3.64±0.67	3.68±0.86	0.84
Self-Confidence	3.45±0.74	3.99±0.68	0.001**
Systematicity	3.98±0.86	4.08±0.88	0.65
Intellectual Fairness	3.52±0.77	3.53± 0.93	0.96
Skepticism	3.56±0.69	3.55± 0.69	0.95
Objectivity	3.55±0.86	3.85±0.73	0.15

Figure 2



DISCUSSION

Critical thinking is an essential competency for medical graduates, vital for ensuring safe practice. Evidence indicates that targeted educational strategies can develop this skill. [18] Gamification, a promising approach, has gained attention for its potential to enhance critical thinking and academic performance. However, its resource-intensive nature and the influence of emerging variables underscore the need for further exploration.[19,20]

This study evaluated the impact of gamification on critical thinking disposition and academic achievement. The results reveal a positive influence in both areas, particularly in the subdomain of self-confidence, aligning with previous findings. For instance, Mao et al documented enhanced critical thinking through game-based learning. Similar observations were reported by McDonald and Lee et al .[21-23]

In addition, students exposed to gamification demonstrated better academic scores compared to the control group. This aligns with studies by Hattie et al and Mayer et al, both of which confirm gamification as an effective knowledge-enhancing strategy.[24,25] The motivational aspect of gamification, driven by enjoyment and engagement, likely contributed to this outcome. Furthermore, enhanced attention and competitiveness within games may also facilitate deeper learning.[26,27]

Moreover, gamified learning fosters collaborative interactions, promoting critical and analytical thinking. In this study, team-based gameplay encouraged students to strategize and prepare collaboratively, leveraging self-directed learning and peer discussion. This aligns with theories of proximal development and schema-building, where collaborative problem-solving leads to deeper conceptual understanding.[28]

CONCLUSION

Gamification has demonstrated significant potential to enhance critical thinking disposition and academic achievement in medical education. By fostering engagement, collaboration, and deeper learning, gamified strategies can serve as a valuable addition to the curriculum. However, further research is warranted to refine its implementation and explore its long-term effects on learning outcomes.

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