Bridging Theory and Practice: Patho-Play as an Innovative Serious Game for Pathology Training in Medical Education

Relier Théorie et Pratique: Patho-Play, Un Jeu sérieux innovant pour l'apprentissage de l'anatomie pathologique en formation médicale

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Abstract

Introduction: Serious games are playing an increasingly important role in medical education. However, their use in pathology remains limited, despite the complexity and high level of rigor of this discipline, which poses a significant challenge for students.
Objective: To evaluate Patho-Play, a scenario-based serious game for pathology training, by assessing short-term knowledge gains and learner perceptions among third-year medical students.
Methods: In a prospective single-arm study over two academic years (2023–2025), 28 third-year medical students completed a 45-minute Patho-Play session comprising 12 sequential levels. Knowledge was assessed using a 20-item multiple-choice pre-test and post-test aligned with the internship logbook. Student perceptions were collected via an anonymous questionnaire. In-game performance scores were recorded to measure engagement.
Results: Pre-test mean scores increased from 12.25 (SD 1.75) to 17.68 (SD 0.95) out of 20 ($p < 0.001$; Cohen's $d = 3.85$). All participants improved by ≥3 points; 50% achieved ≥18/20 post-test. In-game scores (900–1230/1280) reflected task accuracy and hint usage. Student feedback indicated high acceptability: 89% reported added educational value, 86% reported increased engagement, and 79% found the experience immersive. Only 18% perceived enhanced teamwork.
Conclusions: Patho-Play demonstrated potential effectiveness for short-term knowledge gains and high learner acceptability. Given the single-arm design and MCQ-based assessment, results should be interpreted cautiously. Future randomized studies are needed to confirm efficacy, evaluate long-term retention, and explore collaborative and adaptive features.
Keywords: Gamification; Medical Education; Pathology; Game-based learning, Serious Game.

Résumé

Introduction : Les jeux sérieux occupent une place de plus en plus importante dans l'enseignement médical. Cependant, leur utilisation en anatomopathologie reste limitée, malgré la complexité et le haut niveau d'exigence de cette discipline, qui représente un véritable défi pour les étudiants.
Objectif : Évaluer Patho-Play, un jeu sérieux scénarisé, sur les gains de connaissances à court terme et les perceptions des étudiants de troisième année de médecine.
Méthodes : Une étude prospective monocentrique (2023–2025) a inclus 28 étudiants. Ils ont réalisé une session de 45 minutes (12 niveaux). Un pré-test et un post-test de 20 QCM ont évalué les connaissances. Un questionnaire anonyme a recueilli les perceptions. Les scores en jeu ont été analysés.
Résultats : Le score moyen est passé de 12,25 (ET 1,75) à 17,68 (ET 0,95) /20 ($p<0,001$; d de Cohen=3,85). Tous ont progressé d'au moins 3 points ; 50 % ont obtenu ≥18/20. Les scores en jeu (900–1230/1280) indiquaient une bonne précision. Le ressenti fut très positif : 89 % ont signalé une valeur pédagogique, 86 % un engagement accru, 79 % une immersion. Seulement 18 % ont noté une amélioration du travail d'équipe.
Conclusion : Patho-Play apparaît comme un outil prometteur pour renforcer l'apprentissage à court terme et stimuler l'engagement des étudiants en anatomopathologie. Cependant, le design à bras unique et l'évaluation par QCM nécessitent une interprétation prudente. Des études randomisées sont requises afin de confirmer l'efficacité, explorer la rétention à long terme et évaluer les dimensions collaboratives.
Mots-clés : Ludification ; Enseignement médical ; Anatomopathologie ; Apprentissage par le jeu ; Jeu sérieux.

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LA TUNISIE MEDICALE-2026; Vol 104 (03): 395-400 DOI: 10.62438/tunismed.v104i03.6596

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Introduction

Medical education increasingly emphasizes interactive, learner-centered approaches to enhance knowledge acquisition and engagement [1]. Serious games digital applications explicitly designed for learning have emerged as effective tools in this paradigm. By combining structured instructional content with game mechanics, serious games create immersive environments in which learners can acquire, apply, and consolidate medical knowledge and clinical skills within a safe and controlled setting [1,2]. Simulated clinical scenarios encourage active problem-solving, procedural understanding, and decision-making, while immediate feedback facilitates knowledge retention and reflection [1–3]. Despite evidence supporting serious games in fields such as surgery, emergency medicine, and internal medicine, their use in pathology remains limited. Only five studies (Table 1) have evaluated serious games in pathology [4–8], leaving a gap in modernizing teaching in a discipline characterized by abstract concepts, complex visual interpretation, and diagnostic reasoning. To address this gap, we developed Patho-Play, a scenario-based serious game aligned with the third-year pathology internship logbook, and conducted a prospective study to evaluate its short-term impact on knowledge acquisition and student perceptions of usability and educational relevance.

Table 1. Serious Games in Pathology: Literature Review

Authors	Year	Game Theme	Number of participants
Rotaru DC et al., [4]	2016	Cytopathology	NS
Jaquier A et al., [5]	2019	Discovering Pathology	NS
Attaway CC *et al.,* [6]	2022	Enhance communication among residents to establish pathological diagnosis	14
Bhat A et al., [7]	2023	Neoplasia	72
Tang PY et al., [8]	2025	Macroscopic Examination	NS
Limaiem F et al.,	2025	Diagnostic processes within a pathology laboratory	28

***NS**: Not Specified

Methods

Study Design and Population

We conducted a prospective single-arm study over two academic years (2023–2025) among third-year medical students at the Faculty of Medicine of Tunis. We invited all eligible students to participate voluntarily and obtained written informed consent from those who agreed.

Study Population

Target Audience:
The target population included third-year medical students from the Faculty of Medicine of Tunis.

Inclusion Criteria:
All third-year medical students enrolled in the Faculty of Medicine of Tunis during the 2023-2025 academic years were considered eligible for the study. Students were invited to participate voluntarily, and only those who provided written informed consent were included.

Exclusion Criteria:
Students who did not provide informed consent or declined participation were excluded from the study.

Study Setting: The study was conducted across

several pathology departments, including those at Habib Thameur Hospital, Mongi Slim Hospital (La Marsa), the Internal Security Forces Hospital (La Marsa) and Abderrahmen Mami Hospital.

Serious Game Design and Implementation

Conceptual Framework:
The serious game used in this study was meticulously designed based on the learning objectives outlined in the internship logbook for third-year medical students at the Faculty of Medicine of Tunis.

Visual Resources:
All images used within the game were sourced from our institutional image bank.

Game Development:
The serious game *Patho-Play* (Figure 1) was developed using the VTS Editor software (trial version, Serious Factory, Paris, France), an interactive authoring tool designed for creating immersive learning simulations without programming skills. The game was customized to meet the specific educational objectives of third-year medical students during their pathology rotation. Its design was guided by the competencies outlined in the students' official logbook, ensuring alignment with their learning outcomes. *Patho-Play* consists of progressive, scenario-based modules simulating real pathology laboratory situations. Although the VTS Editor software is commercially available from Serious Factory, the *Patho-Play* version used in this study was developed locally for research and educational purposes and is not publicly available for external evaluation.

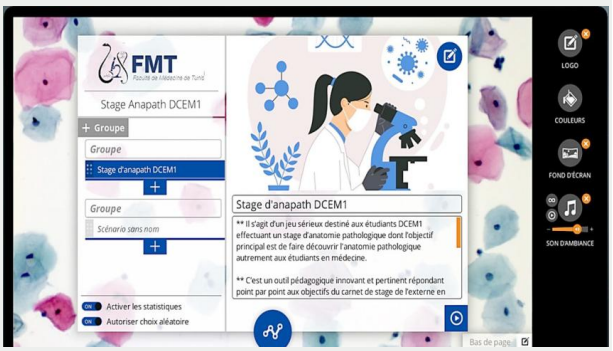


Figure 1. Screenshot of the serious game interface: A visual representation of the game's user interface, showcasing its design, functionalities, and interactive elements.

Core Gameplay Mechanics and Learning Process:
Patho-Play relies on a structured quiz-based gameplay loop in which students progress through short clinical and laboratory scenarios by answering multiple-choice questions, True–False items, and image-selection tasks. Each activity requires learners to observe digital histological slides, macroscopic specimens, or short video sequences before choosing the appropriate action or diagnostic option. The interaction is primarily point-and-click, allowing students to navigate scenes, review visual material, and select their responses directly on screen. The learning process is driven by immediate automated feedback: each answer triggers a brief explanation highlighting the correct reasoning, while incorrect choices generate clarifications and prompts that reinforce key concepts. This rapid feedback loop supports active learning, encourages reflection, and ensures that students consolidate knowledge as they advance through the game. A cumulative score is displayed throughout the session, enabling learners to monitor their performance and engagement.

Game Structure:
The game consists of twelve sequential levels that mirror the workflow of a pathology laboratory, beginning with safety procedures and specimen reception before moving on to gross examination, tissue processing, microscopic analysis, immunohistochemistry, frozen section interpretation, and communication of diagnostic results. Communication-related learning was delivered through an interactive branching scenario in which students selected dialogue options during a simulated clinician–pathologist exchange, allowing them to explore appropriate phrasing and ethical considerations when presenting diagnostic findings. Each level introduces a focused objective from the pathology internship logbook and concludes with a set of quiz-based challenges using the formats described above. As students progress, the clinical scenarios become more complex, requiring the integration of visual cues with diagnostic reasoning. Completion of the full sequence takes approximately 45 minutes and provides a compact yet comprehensive overview of essential pathology concepts and skills (Figure 2).

Implementation:
The gaming session was held in the hospital staff room, where participants gathered with the instructor (Figure 3). The instructor began by explaining the game's objectives and rules. A debriefing session was held afterward, allowing students to reflect on the experience, share feedback, and discuss the learning outcomes.

Assessment of Learning Outcomes

Learning outcomes were evaluated using a 20-item multiple-choice questionnaire administered both before (pre-test) and after (post-test) the game session. The questions covered a broad range of pathology topics aligned with the students' internship logbook and the content of the serious game, including histological techniques, immunohistochemistry, specimen processing, histological image interpretation, and communication skills for delivering diagnoses. Each question was worth one point. The pre- and post-tests were developed by two senior pathologists based on the official internship logbook and the core learning outcomes of the third-year pathology curriculum. All items were mapped to predefined competencies, including histological techniques, specimen handling, and basic diagnostic reasoning. Two distinct types of scores were collected in this study. The first were the pre- and post-test scores (0–20), based on the 20-item multiple-choice questionnaire administered before and after the intervention. The second were the in-game performance scores generated automatically by the VTS Editor engine during gameplay. These in-game scores (0–1280) reflected the accuracy of responses, penalties for incorrect actions, and any use of hints within each scene. Game performance was assessed based on participants' scores during gameplay. Statistical analysis involved tests for normality (Kolmogorov-Smirnov and Shapiro-Wilk) to ensure the data followed a normal distribution. Descriptive statistics (means, medians, and standard deviations) were calculated, and paired sample t-tests were used to compare pre-test and post-test scores, with statistical significance set at $p < 0.001$. Effect size ($r > 0.8$) was also calculated to determine the magnitude of the observed differences. Both Kolmogorov–Smirnov and Shapiro–Wilk tests were applied to verify the assumption of normality required for the paired t-test; Shapiro–Wilk was prioritized because it is recommended for small samples.

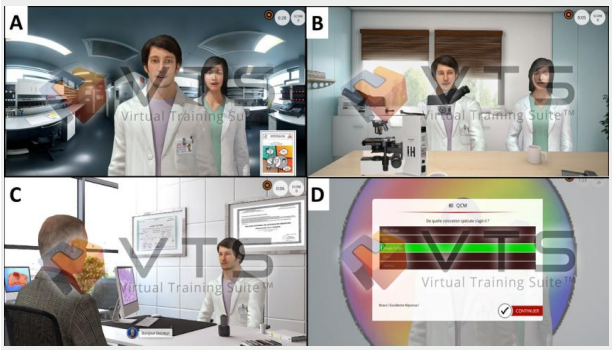


Figure 2.
A: Screenshot of the serious game's first scene: Welcoming medical externs and presenting the objectives of the internship logbook.
B: Screenshot of a scene from the serious game in the staff room, where medical externs are tasked with interpreting histological slides of common pathologies.
C: Screenshot of the serious game background: A scene illustrating the announcement of a cancer diagnosis – Learning ethical reasoning
D: Screenshot showing a correct answer provided by students to a multiple-choice question.

Evaluation of Student Satisfaction

Upon completion of the game-based sessions, students were invited to complete an anonymous evaluation questionnaire (see Supplementary File) to share their opinions on the educational value of the game. Responses were rated using Likert scales.



Figure 3. Illustration of third-year medical students playing the serious game *PathoPlay.*

Ethical Considerations and Conflict of Interest

Ethical principles were strictly upheld throughout the study. Written informed consent was obtained from all participants, including consent for the use of photographs taken during the sessions. To ensure confidentiality, participants were assigned anonymized alphanumeric identifiers. All data were securely stored and accessible only to authorized personnel. There are no conflicts of interest to declare. The study received approval from the Institutional Ethics Committee of Mongi Slim Hospital, Tunisia.

Results

Participant Characteristics

We invited 32 students to participate, and 28 (87.5%) enrolled, including 23 females and 5 males. None of the participants had prior experience with serious games during clinical rotations.

In-Game Performance

We assessed participants' performance during the Patho-Play sessions using the game's built-in scoring system (0–1280 points), which reflected accuracy, hint usage, and task completion. Scores ranged from 900 to 1230, with a mean of 1062.1, a median of 1060, and a standard deviation of 67.3, indicating moderate variability in performance across the cohort (Figure 4).

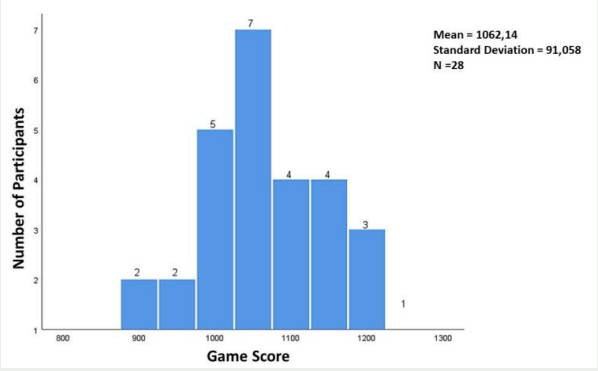


Figure 4. Histogram illustrating the distribution of participants' scores achieved during the Patho-Play serious game, highlighting performance variability across the cohort.

Pre-Test and Post-Test Knowledge Scores

For the pre-test scores, the minimum score recorded was 8.5, with a maximum of 15, and the mean score was 12.25 ±1.75, indicating a moderate level of variation in the participants' initial performance. In contrast, post-test scores showed a higher range, with the minimum score increasing to 16 and the maximum score reaching 20. The mean post-test score was 17.68 ± 0.95, demonstrating a significant increase in participants' overall scores and a reduction in variability compared to the pre-test.

Statistical Analysis

The improvement in test scores following the Patho-Play intervention was statistically significant ($p < 0.001$), indicating that the observed learning gains were highly unlikely to be due to chance. The effect size was exceptionally large (Cohen's $d = 3.85$), underscoring the substantial educational impact of the game. All students (100%) improved their scores by at least 3 points between the pre- and post-test, and no student performed worse after the intervention. Notably, 14 students (50%) achieved near-perfect scores (≥18/20) on the post-test, whereas none had reached this threshold beforehand. Figure 5 presents a box plot comparison of pre-test and post-test scores, clearly illustrating the marked improvement in student performance following the serious game experience. No statistical comparison was conducted between in-game scores and test scores because they measure distinct constructs on different scales. However, exploratory correlation suggested no strong linear association. Descriptive statistics, normality test results, and paired comparisons of pre-test, post-test, and game performance scores are summarized in Table 2. No statistical comparison was conducted between in-game scores and test scores because they measure distinct constructs on different scales. However, exploratory correlation suggested no strong linear association.

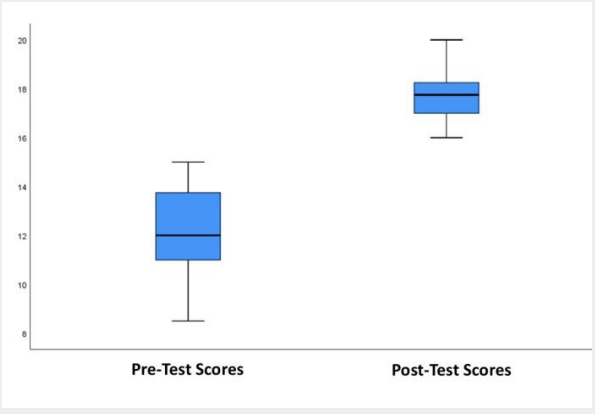


Figure 5. Box plot comparison of pre-test and post-test scores of third-year medical students before and after playing the serious game "Patho-Play."
The pre-test scores show a lower median and wider distribution, indicating varied baseline knowledge. In contrast, post-test scores demonstrate a significant improvement with higher median values and reduced variability, reflecting enhanced understanding following the game-based intervention.

Table 2. Summary of Pre-Test, Post-Test, and Game Score Statistics with Paired Comparisons

Category	Pre-Test	Post-Test	Game Scores	Paired Comparison (Pre vs. Post)
Normality Tests				
Kolmogorov-Smirnov (p)	0.200*	0.080	0.200*	–
Shapiro-Wilk (p)	0.291	0.183	0.577	–
Descriptive Statistics				
Mean (±SD)	12.25 ± 1.83	17.77 ± 0.92	1062.14 ± 91.06	Mean Difference: -5.52 ± 1.34
Median	12.00	17.75	1055.00	–
Range (Min–Max)	8.5 – 15.0	16.0 – 20.0	900 – 1230	95% CI: [-6.04, -5.00]
Percentiles (Q1–Q3)	11.00 – 13.88	17.00 – 18.38	985.00 – 1140.00	–
Inferential Statistics				
Test Statistic (t)	–	–	–	t = -21.731
Degrees of Freedom (df)	–	–	–	df = 27
p-value (2-tailed)	–	–	–	p < 0.001
Effect Size	–	–	–	Large (r > 0.8)

*: Lower bound of the exact p-value (Lilliefors-corrected Kolmogorov-Smirnov test).

Students' Perceptions and Experience with the serious game *Patho-Play*

All students completed the satisfaction questionnaire after using the Patho-Play serious game.

Educational objectives: 82% of respondents (23/28) agreed or strongly agreed that the game aligned well with the learning objectives of the pathology internship.

Engagement and stimulation: 86% (24/28) found the game engaging and motivating.

Immersive experience: 79% (22/28) felt that the game offered a realistic and immersive experience in a pathology laboratory.

Promotion of critical thinking: 75% (21/28) stated that the game encouraged critical thinking and the practical application of knowledge.
Collaboration: 18% (5/28) reported that the game promoted teamwork and peer collaboration.

Added educational value: 89% (25/28) believed the game provided added value compared to traditional learning methods. Participants rated the difficulty of Patho-Play as follows: no students considered it "extremely easy" (1), two students rated it as "rather easy" (2), fourteen students found it "moderate" (3), eleven rated it as "rather difficult" (4), and one student described it as "extremely difficult" (5). Additionally, 29% of participants (8/28) mentioned in the open comments section that the game was time-consuming, with suggestions to shorten the duration of video sequences in order to improve pacing and maintain engagement. When asked whether they would recommend Patho-Play for future pathology rotations, 93% (26/28) of students expressed a positive response, indicating a willingness to recommend the game to their peers, while the remaining 7% (2/28) were neutral, and no students opposed its reuse.

Discussion

In our study, the design of Patho-Play was firmly grounded in experiential learning theory, which posits that knowledge is actively constructed through cycles of engagement, feedback, and reflection. By providing immediate corrective feedback, the game guides learners toward essential information while reducing extraneous cognitive load. Its interactive and progressive structure fosters intrinsic motivation, consistent with Self-Determination Theory, supporting autonomy, competence, and engagement throughout the learning process [1,9-11]. Our findings demonstrate that Patho-Play significantly enhanced pathology knowledge among third-year medical students, with mean test scores rising from 12.25 to 17.68 ($p < 0.0001$; Cohen's $d = 3.85$). All participants improved by at least three points, and half achieved near-perfect scores (≥18/20). These robust outcomes align with Xu et al. [1], highlighting the growing relevance of game-based learning in medical education, and reinforce Gorbanev et al.'s [2] systematic review on the effectiveness of serious games in improving cognitive outcomes. Importantly, these substantial gains were achieved in a concise 45-minute session, supporting Shrivastava et al.'s [3] assertion that well-designed serious games can efficiently deliver targeted instruction without prolonged time investment. Patho-Play advances the field of pathology education by integrating multiple dimensions of competency. While prior studies, such as Tang et al. [8], focused on macroscopic pathology or Rotaru et al. [4] emphasized cytological interpretation, Patho-Play combines macroscopic and microscopic diagnostic perspectives, procedural laboratory skills, and communication training for delivering difficult diagnoses. This multidimensional approach responds directly to Xu et al.'s [1] call for educational tools that develop both cognitive and practical competencies, and addresses Gong et al.'s [12] identified need for interventions that go beyond knowledge acquisition to encompass clinical reasoning, ethical decision-making,

and patient interaction. Student engagement was notably high, with 86% reporting active participation and 75% expressing increased confidence in slide analysis. These results echo Jacquier et al. [5], who documented the motivational power of immersive simulations, and Attaway et al. [6], whose work with the Pathology Pyramid showed cognitive improvements in residents' diagnostic reasoning. The strong effect size of our intervention (Cohen's d = 3.85) underscores the impact of combining visual, interactive, and procedural tasks with immediate feedback, demonstrating that serious games can facilitate deep learning and reinforce practical skills concurrently. The study also confirms that serious games can act as effective pedagogical tools across multiple dimensions. Patho-Play's integration of clinical scenarios, technical laboratory skills, and communication training supports the dual role of serious games as both educational and engagement platforms, as outlined by de Matos Lima et al. [9]. Furthermore, our results align with meta-analytic evidence by Nylén-Eriksen et al. [11], demonstrating that serious games improve knowledge acquisition (ES=1.06) and skill development (ES=0.54), and with Gong et al. [12], who found serious games outperforming conventional methods in the majority of comparative studies. Despite these strengths, the study shares several limitations common in medical education research. The sample size (n=28), though sufficient for detecting statistical significance, was modest, reflecting small group rotations and voluntary participation. This limits generalizability and highlights the need for larger, multicenter studies to confirm the observed effects. The current single-player format likely contributed to only 18% of students perceiving improved teamwork, suggesting future iterations should incorporate collaborative or multiplayer modes to enhance peer learning. Additionally, some participants noted that video sequences were time-consuming, indicating the need to optimize pacing and streamline media content. While our study focused on short-term outcomes, long-term knowledge retention, skill transfer, and translation into clinical competence remain areas for future investigation. Integrating adaptive learning algorithms, virtual reality components, and AI-driven personalized feedback could further enhance the educational impact, building on the frameworks proposed by Shrivastava et al. [3], Tang et al. [8], Attaway et al. [6], and de Matos Lima et al. [9]. Furthermore, the technical requirements of digital game-based learning may pose challenges in resource-limited settings, a factor previously noted by Gorbanev et al. [2]. Compared with existing pathology-related games, Patho-Play provides broader competency coverage, integrating macroscopic, microscopic, procedural, and communication tasks within a single, cohesive learning experience. This contrasts with previous tools that predominantly targeted isolated skills, such as cytology interpretation or gross examination. Beyond pathology, our results are consistent with gamified learning studies in surgery, emergency medicine, and nursing education, which similarly report increased engagement, motivation, and short-term knowledge gains [1,3,6]. Overall, Patho-Play demonstrates the transformative potential of serious games in pathology education. By delivering efficient, engaging, and multidimensional instruction, the game fosters knowledge acquisition, practical skill development, and learner confidence. These findings provide a strong pedagogical rationale for integrating serious games into medical curricula while also identifying actionable areas for future development, including collaborative learning, adaptive difficulty, and immersive technologies.

Conclusion

Patho-Play significantly improved short-term pathology knowledge and was highly accepted by third-year medical students. While the single-arm pre/post design and small sample size limit generalizability, the study demonstrates the potential of serious games as effective, multidimensional educational tools. Future research should include randomized controlled trials, larger cohorts, longitudinal follow-up, and evaluation of knowledge retention, reasoning skills, teamwork, and clinical application. Incorporating adaptive algorithms, collaborative gameplay, and immersive technologies could further enhance Patho-Play's impact and support its integration into competency-based medical education.

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