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Systematic Review

The integration of gamification strategies within competency-based otorhinolaryngology residency training: a comprehensive analysis of pedagogical shifts, technological implementations and professional outcomes in the U. S. medical education system

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ABSTRACT

Postgraduate medical education is transitioning toward a structured competency-based medical education (CBME) framework, utilizing ACGME Milestones 2.0 and Entrustable Professional Activities (EPAs) to objectively measure resident progression from novice to expert. Objectives were to evaluate the integration of gamification strategies, applying game-design elements within non-game settings, in otorhinolaryngology residency, specifically analyzing their impact on learner engagement, operative technical proficiency, and professional outcomes. A comprehensive analysis evaluated the implementation of digital pedagogy (e.g., podcasts, microblogging), workplace-based assessment platforms (EMYWAY), cognitive judgment tools (SICKO), and immersive simulations (VR/AR/MR) for core surgical skills acquisition. Educational preferences are shifting toward digital resources; notably, residents engaging in gamified discussions on platforms like Twitter increased their ABSITE percentile rank by an average of 13.7%. Digital assessment tools such as EMYWAY foster a shared understanding of competency between faculty and trainees ($r=0.531$). Furthermore, VR simulations for emergency procedures and temporal bone surgery significantly enhance procedural accuracy, with VR cricothyrotomy improving performance in 92% of participants. Tools like SICKO also effectively differentiate surgical expertise levels ($p=0.001$). Gamification effectively modernizes surgical training by bridging the gap between theoretical knowledge and operative mastery. Strategic recommendations emphasize integrating validated simulators and AI-driven adaptive learning into weekly training to support objective entrustment decisions.

Keywords: Gamification, Competency-based medical education, Otolaryngology, Virtual reality, Entrustable professional activities

INTRODUCTION

The landscape of postgraduate medical education in otorhinolaryngology is currently traversing a fundamental transformation, transitioning from the traditional, time-bound apprenticeship models characterized by the Halstedian "see one, do one, teach one" philosophy toward a structured, outcome-oriented framework known as CBME.[1,2] This shift is necessitated by an increasing demand for standardized educational outcomes, enhanced

patient safety, and a more granular approach to assessing trainee progression in an era of restricted resident work hours and escalating clinical complexity.[3] Within this evolutionary context, gamification-the strategic application of game-design elements and mechanics in non-game environments-has emerged as a potent catalyst for enhancing engagement, knowledge retention, and technical proficiency among surgical residents.[4-7]

The implementation of the Accreditation Council for Graduate Medical Education (ACGME) Milestones and the parallel development of EPAs provide the necessary scaffolding for this competency-driven approach.[8,9] These frameworks allow for the objective measurement of a resident's journey from a novice to an expert, yet they also introduce challenges regarding learner motivation and the objective evaluation of performance in the workplace.[10] Gamification addresses these challenges by leveraging intrinsic and extrinsic motivators-such as competition, achievement, and social relatedness-to foster a more dynamic, interactive, and transparent learning environment.[5,7,11,12]

METHODS

This systematic review was conducted in accordance with PRISMA 2020 guidelines to analyse the integration of gamification within competency-based otorhinolaryngology training. A narrative synthesis approach was adopted due to the profound heterogeneity of interventions-ranging from VR/AR simulations and AI-driven adaptive platforms to workplace-based assessment tools-which precluded a formal meta-analysis.

A comprehensive search was executed in January 2026 across PubMed, Scopus, Web of Science, Embase, the Cochrane Library, and ERIC. The strategy utilized high-sensitivity Boolean strings such as ("gamification" OR "serious games" OR "virtual reality") AND ("otorhinolaryngology" OR "head and neck surgery") AND ("CBME" OR "milestones"). Eligibility focused on ENT residents and faculty (Population), gamification and CBME implementation (Concept), and academic or simulation settings (Context). Inclusion was restricted to English-language, peer-reviewed original research-including RCTs, quasi-experimental, and validation studies-published between 2005 and 2026.

Study selection involved independent dual-reviewer screening and full-text assessment, with discrepancies resolved through senior adjudication. Data extraction focused on gamification elements (e.g., leaderboards, feedback), educational domains (technical vs. cognitive skills), and outcome measures (e.g., entrustment levels). Synthesis followed thematic approach, mapping technological interventions against ACGME Milestones 2.0 and EPA frameworks to evaluate institutional and professional outcomes. Selection process identified 1,964 records through databases and 126 through manual searches (n=2,090). After removing 438 duplicates, 1,652 records were screened, resulting in the exclusion of 1,289 reports. Of the 363 full-text articles assessed, 326 were excluded: 107 were not ENT-specific, 95 lacked CBME relevance, 56 had no measurable outcomes, 38 were conference abstracts, and 30 non-English. Consequently, 37 studies met all inclusion criteria and were incorporated into the final synthesis, providing a robust evidentiary basis for the analysis of digital pedagogy in specialty (Figure 1).

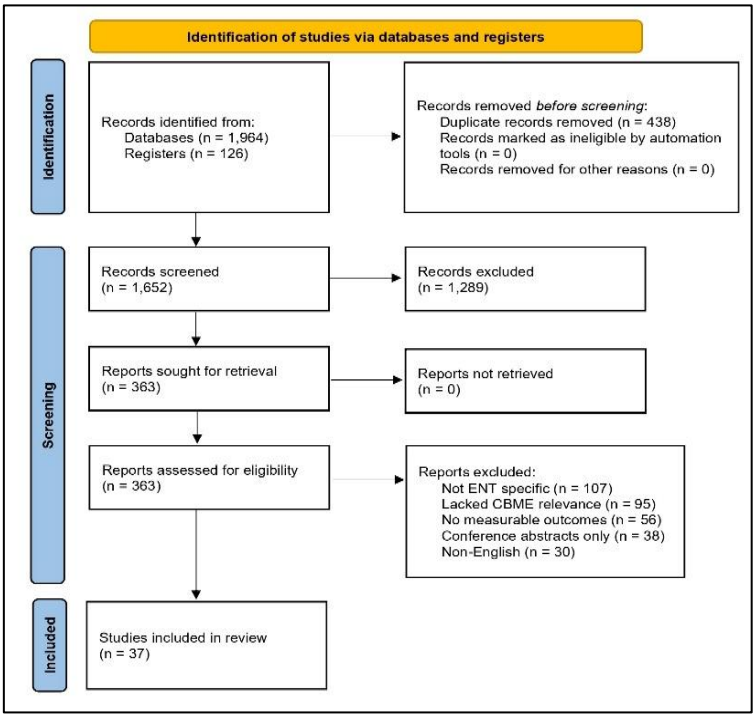

Figure 1: PRISMA flow diagram.

RESULTS

Theoretical foundations of gamified learning in surgical residency

The theoretical underpinnings of gamified learning suggest that instructional content, when augmented with game characteristics, can fundamentally alter learner behaviours and attitudes.[5,7] This transition from conventional, passive teaching methods to innovative pedagogical strategies is pivotal for ensuring higher retention rates and fostering a lifelong learning mindset among modern surgical trainees.[13] Gamification in medical education is defined as the addition of game elements-such as points, leaderboards, gradable content, and immediate feedback-to enhance user engagement with educational material.[14,15] The major principles of Gamification elements in medical education is listed in Table 1.

A critical distinction must be maintained between "serious games"-which are full-fledged video games designed for an industry-specific purpose-and "gamified platforms," which integrate specific game elements into existing educational goals.[16] In otorhinolaryngology, while simulation-based trainers for temporal bone surgery often qualify as serious games, the broader application of gamification involves enhancing didactic lessons and workplace-based assessments with competitive and reward-based mechanics.[17]

The efficacy of these strategies is often analyzed using the Structure of Observed Learning Outcomes (SOLO) taxonomy.[18] Analysis of empirical studies in medical education reveals that while the majority of gamified interventions currently achieve uni-structural or multi-structural learning outcomes, there is an emerging trend toward fostering relational and extended-abstract thinking through more sophisticated game designs.[19] Consonant with this, research indicates that the combination of points, badges, and leaderboards is significantly more effective in enhancing intrinsic motivation and reducing amotivation than isolated elements, as the richer interaction of these components creates a more unified and immersive system.[20]

The architecture of CBME in otorhinolaryngology: milestones and EPAs

Central to the modernization of otorhinolaryngology training is the implementation of the ACGME Milestones 2.0, which were finalized in 2021 and implemented in the 2022-2023 academic year.[8] These milestones provide a developmental framework for assessing residents across six core competencies: patient care, medical knowledge, systems-based practice, practice-based learning and improvement, professionalism, and interpersonal and communication skills.[3,10] Unlike previous iterations, Milestones 2.0 are fewer in number, stated in more straightforward language, and include harmonized sub-competencies across all surgical specialties, facilitating a more consistent evaluation process (Table 2).[8]

Complementing the milestones are EPAs, which focus on the holistic assessment of a learner's ability to perform specific clinical tasks.[1,9] An EPA integrates multiple competencies into a single, observable activity, such as managing facial trauma or performing a mastoidectomy.[9,10] In Taiwan, the Society of Otorhinolaryngology-Head and Neck Surgery (TSO-HNS) developed the EMYWAY platform, a workplace-based assessment framework that integrates 11 specific EPAs with milestone-based tracking.[9] This platform utilizes a 5-level entrustment-supervision scale, where Level 1 allows only observation and level 5 permits independent practice.[9]

Data from the EMYWAY pilot and full-scale implementation underscores the utility of these digital frameworks. Over 9,800 responses were recorded in a single year, with the most frequent evaluations occurring in the surgical theatre (45.9%) and focusing on "head and neck" (17.5%), "sinonasal" (13.5%), and "ear" (12.2%) EPAs. Significantly, task complexity was shown to increase with resident seniority, and a positive correlation ($r=0.531$, $p<0.001$) was found between residents' self-assessments and faculty ratings, suggesting that these platforms foster a shared understanding of competency. Gamification elements, such as progress dashboards and real-time entrustment level visualization, act as powerful motivators for residents to actively seek assessments and feedback.[9]

Digital pedagogy and the rise of non-traditional educational resources

The educational habits of practicing and training otolaryngologists have shifted dramatically over the past decade, with a marked decline in traditional textbook usage and a significant increase in the adoption of digital, on-demand resources. Podcasts, in particular, have emerged as a dominant tool for peer-to-peer education, offering an accessible and engaging format that can be seamlessly integrated into a busy clinical schedule. The BackTable ENT podcast exemplifies this trend, providing a narrative learning experience that promotes empathy, reflection on practice, and professional identity formation.[20]

Beyond podcasts, gamified study tools have demonstrated a direct impact on formal examination performance. A landmark study by Alexander et al showed that the gamification of online study tools for the Otolaryngology Training Examination had a measurably positive impact on resident scores.[21] Consonant with this, the use of microblogging platforms like Twitter for resident education has proven effective. Residents participating in gamified case discussions on Twitter increased their ABSITE percentile rank from 2016 to 2017 by an average of 13.7% (±14.1%), whereas

nonparticipants saw a decrease of 10% (±16.6%, p=0.003) (Table 3).[22]

The psychological mechanism behind these successes is often tied to the "Theory of Gamified Learning," which posits that instructional content influences learning outcomes primarily through changes in learner behaviour and engagement.[5] For instance, quiz-based applications like Kahoot! enhance cognitive engagement by providing immediate feedback and fostering a sense of competition.[4,5] This is particularly critical in fields like pharmacology or oncology, where the volume of information is vast and traditionally taught through passive methods.[4,13,23]

Immersive simulations and technical proficiency in ENT

In the surgical domain of otorhinolaryngology, technical proficiency is the bedrock of safe practice. Virtual reality (VR), augmented reality (AR), and mixed reality (MR) simulations have become indispensable tools for training in a risk-free environment.[24,25] These systems provide the repetitive practice and controlled environment necessary to master the complex 3D anatomy of the ear, nose, and throat.[26,27]

A systematic review of temporal bone simulators identifies five validated platforms: Voxel-Man, CardinalSim, the Ohio State University Simulator, the University of Melbourne's VR Surgical Simulation, and the Visible Ear Simulator.[28] These simulators utilize computer-generated imagery and often integrate haptic feedback to mimic the tactile sensation of drilling bone.[29] The visible ear simulator, for instance, has been shown to improve performance in cadaveric mastoidectomy dissection through the use of automated summative feedback.[30] In a prospective study, an intervention group that utilized structured self-assessment during VR training achieved a performance score of 11.8 points in subsequent cadaveric dissection, significantly higher than the 9.1 points achieved by the control group.[30]

Emergency procedures, such as cricothyrotomy, also benefit from gamified VR training. A study involving 149 students utilized a unity-based VR cricothyrotomy scenario that implemented a point system and time pressure. Participants had two minutes to perform six critical steps: palpation of the throat, vertical skin incision, horizontal severance of the cricothyroid ligament, maintaining the airway with the scalpel handle, insertion of the endotracheal tube and ventilation.[15]

The simulator "punished" errors with point deductions, such as-10 points for failing to use gloves or -30 points for an incorrect incision direction. The results showed that 92% of participants improved their procedural accuracy, with an average completion time of 47±16 seconds and a mean score of 8.7 out of 9 possible points.[15] The use of various VR platforms for various procedures in outlined in Table 4.

The broader implications of these findings suggest that immersive VR not only enhances technical skill acquisition but also predicts or correlates with an individual's performance in the actual operating room. As technology evolves, systems like the ExR platform are delivering 360-degree video walkthroughs and 6DOF (six degrees of freedom) interactive simulations, allowing residents to experience "limitless" operations and emergencies from remote locations.[37]

Cognitive skills and surgical decision-making: The SICKO platform

The acquisition of psychomotor skills is only one half of surgical competence; the other half is clinical reasoning and operative judgment.[2] Traditional simulations often neglect non-technical skills, focusing instead on manual dexterity. To address this gap, the surgical improvement of clinical knowledge Ops (SICKO) platform was developed to provide a valid assessment of surgical decision-making. In a pilot study involving 49 subjects stratified into four levels of expertise, SICKO was used to measure cognitive performance in surgical scenarios. The game-based assessment proved highly effective at differentiating skill levels based on total score.[16]

The statistical significance of these score differences (p=0.001) provides strong validity evidence for gamified platforms as objective tools for measuring clinical and operative judgment. Furthermore, survey results from participants revealed high scores for the realism and content of the platform, indicating that the gamified format did not detract from the perceived professional value of the exercise.[16]

A similar approach is seen in the development of SDMentor (Surgical decision-making mentor), an intelligent tutoring system that integrates VR simulation with a conversational agent to teach the rationale behind surgical decisions.[34] By representing surgical procedures using Planning Domain Definition Language (PDDL), the system can offer tailored, real-time feedback and guidance, mimicking the interactions between a master surgeon and a trainee. These systems promote self-directed learning and allow residents to practice complex decision-making in a risk-free, asynchronous format.[34,35]

Artificial intelligence and the future of adaptive learning

The convergence of artificial intelligence (AI), AR, and VR represents a paradigm shift in medical education.[32,36,37] AI-driven personalization allows training scenarios to be dynamically adjusted based on the learner’s performance, a concept often referred to as "adaptive gamification".[22,29] Imagine an ENT resident performing a virtual thyroidectomy while AI analytics

assess their hand-eye coordination and spatial awareness in real-time, automatically increasing the difficulty or introducing a sudden complication-such as a recurrent laryngeal nerve proximity-based on the resident's growth over time.[29,32]

AI-based assessments also offer a solution to the inherent subjectivity of traditional faculty feedback. By analysing simulation data, such as tool path trajectory, velocity, and force applied, AI can produce reproducible and unbiased metrics that more effectively differentiate skill levels than traditional global rating scales.[38] Consonant with this, natural language processing (NLP) is being explored as a tool to facilitate the complex reviews conducted by Clinical Competency Committees (CCCs) by synthesizing text from end-of-rotation assessments to estimate milestone ratings.[39]

In the realm of imaging, deep learning algorithms are being utilized for the automated segmentation of the inner ear from CT and MRI scans. A multicenter study optimized an open-source U-net model that achieved a Dice similarity coefficient of 0.83, significantly reducing the time required for surgical planning. Gamifying these segmentation tasks-perhaps through competition among residents to achieve the highest accuracy score-could accelerate the acquisition of advanced anatomical visualization skills.[40]

Table 5 lists the various available AI technologies and their benefit to Otorhinolaryngology education.

Institutional challenges, costs, and faculty adoption

Despite the documented benefits of gamification and immersive simulation, significant institutional barriers remain. A common concern among educators is the "superficial" use of game elements, where mechanics like points are implemented without deep integration into instructional objectives.[6,7] For gamification to be successful, it must be viewed as an educational design process rather than a standalone teaching method.

Furthermore, the costs associated with high-fidelity simulation and gamified platform development can be prohibitive.[42,43] Project budgets for advanced VR simulations can reach several hundred thousand dollars. This creates a "digital divide" where only well-funded residency programs can afford the most advanced training tools. However, the emergence of low-cost, scalable solutions like ExR-which uses a blended format of 360-degree video and VR-offers a path forward for programs with more limited resources.[28] The strategies for mitigation are explored in Table 6.

Faculty "buy-in" is perhaps the most critical factor for long-term success.[43] Program directors must advocate for the adoption of simulation within the curriculum to elevate learner engagement. This is particularly relevant in the context of resident wellness; with burnout rates among otolaryngology residents averaging nearly 59%, gamified education can provide a more supportive and enjoyable learning environment that mitigates stress.[44]

Table 1: Principles of gamified learning in surgical residency.

Principle category	Specific gamification element	Educational utility
Design principles	Integration with objectives	Ensures alignment between gameplay and clinical goals[6]
Design principles	Freedom to fail	Encourages risk-taking and learning from errors without harm[6]
Design principles	Narrative storylines	Sustains long-term interest and provides clinical context[14,16]
Game mechanisms	Rapid feedback	Identifies knowledge gaps and technical errors in real-time[6,17]
Game mechanisms	Points and scoring	Provides a quantitative measure of progress and achievement[6,18]
Game mechanisms	Leaderboards	Fosters healthy competition and social comparison[6,11,19]

Table 2: Levels of milestones of CBME in otorhinolaryngology and their characteristics and context.

Milestone level	Descriptive characteristic	Otorhinolaryngology context (airway management)
Level 1	Novice/ assistant	Identifies potential airway emergencies as part of a team[10]
Level 2	Developing learner	Performs assessment and focused history/physical; escalates care[10]
Level 3	Intermediate competence	Performs routine surgical management under direct supervision[10]
Level 4	Proficient/ independent	Performs routine surgical management; manages common complications[10]
Level 5	Expert/ consultant	Adapts techniques to special circumstances; manages complex cases[10]

Table 3: Non-traditional educational resources and their impact on outcomes.

Educational tool	Gamification elements used	Impact on outcomes
Twitter microblogging	Social interaction, case-based competition	Increase in ABSITE percentile[26]
Online study modules	Points, badges, leaderboards	Higher training exam scores[24,25]
BackTable ENT podcast	Storytelling, peer interaction	Improved clinical practice and identity[23]
Kahoot! pharmacology	Quiz-based competition, streaks	Enhanced knowledge and learner satisfaction[4]
Onco-blast oncology	Geek/Fun modes, global leaderboards	Faster learning of complex medical data[27]

Table 4: Simulation platforms and their effect on technical proficiency in ENT.

Procedure type	Training platform	Primary outcome
Temporal bone surgery	Voxel-Man /CardinalSim	Enhanced spatial awareness and drilling skill[30,31]
Cricothyrotomy	Unity-based VR	Improved speed and procedural accuracy[17,31]
Mastoidectomy	Visible ear simulator	point improvement in cadaver performance[33]
Sinus surgery	McGill simulator	Validity for residency education[30]
Pediatric bronchoscopy	ExR (Extended reality)	Increased access to rare emergency scenarios[28]

Table 5: AI technologies and their benefit to otorhinolaryngology education.

AI technology	Medical education application	Benefit to otorhinolaryngology
Large language models	Virtual patient interactions	Enhanced history-taking and diagnosis skill[41]
Computer vision	Technical skill analysis	Objective, kinematic-based performance metrics[32,38]
Deep learning (U-net)	Image segmentation	Mastery of 3D inner ear and sinus anatomy[40]
NLP analytics	CCC decision support	More consistent and transparent milestone rating[39]

Table 6: Challenges to implementation of gamification in ENT training and strategies for mitigation.

Implementation challenge	Underlying cause	Potential strategy for mitigation
Faculty resistance	Skepticism of "play" in education	Advocate for high-fidelity simulation to foster buy-in[43]
High development cost	Complexity of VR/AI programming	Utilize open-source platforms like unity/blender[17,40]
Lack of Standardization	Variability in milestone content	Align game metrics with ACGME 2.0 standards[8,10]
Resident burnout	High clinical load and debt	Integrate wellness modules and protected time[44]

Socio-professional impact: salaries, and resident well-being

The economic reality of residency training also influences educational choices. Residents in high-cost-of-living areas experience significant "salary reductions" post-adjustment; for example, a resident in Manhattan may see an effective stipend decrease of 56%. Consonant with this financial pressure, the adoption of low-cost, digital educational tools is not just a pedagogical choice but a necessity for trainees managing substantial debt.[28,44]

Gamification, by providing on-demand, risk-free training, can improve the efficiency of skills acquisition, potentially freeing up non-clinical time which has been shown to increase well-being and reduce burnout.

Moreover, formal mentorship programs-which can be enhanced through gamified social interaction platforms-further contribute to a reduction in trainee stress.[44]

Synthesis and strategic recommendations for ENT educators

The integration of gamification in otorhinolaryngology residency training is a multifaceted endeavour that requires the careful alignment of technology, pedagogy, and institutional culture. The transition to ACGME Milestones 2.0 and the EPA framework provides a robust structure for this integration, but the potential of these tools has not yet been fully realized by the broader medical community.[14,15]

DISCUSSION

Based on the evidence analysed, the following strategic recommendations are proposed for otorhinolaryngology residency programs.

First, programs should prioritize the use of validated simulators for core procedures such as temporal bone surgery and cricothyrotomy, ensuring that these are deeply integrated into the weekly training schedule rather than treated as optional adjuncts.[17,20,31] The use of automated, objective feedback within these platforms is essential for maximizing learning outcomes.[32,33]

Second, the medical educational community should move toward a more standardized definition and implementation of gamification elements.[14] By focusing on the 13 key elements of successful gamification—particularly fairness, rapid feedback, and alignment with instructional goals-educators can ensure that competitive mechanics enhance rather than distract from clinical learning.[6]

Third, programs should embrace non-traditional resources like gamified podcasts and social media microblogging as legitimate components of a blended learning curriculum.[23,26] These tools are especially effective for knowledge-based competencies and examination preparation, areas where traditional lecture models often fail to sustain engagement.[5,13]

Fourth, as AI and adaptive learning technologies continue to mature, residency programs must begin to pilot these solutions for personalized skill assessment and feedback.[29,32] The use of AI to analyse kinematic data from surgical simulators will provide a level of objective evaluation that was previously unattainable, allowing for more confident entrustment decisions.[38]

Finally, the otorhinolaryngology community must address the institutional and financial barriers to widespread adoption.[7,42,43] This includes advocating for funding, supporting faculty development in digital pedagogy, and ensuring that gamified platforms are designed with the specific needs and wellness of the contemporary resident in mind.[43,44]

CONCLUSION

Gamification offers a transformative approach to otorhinolaryngology education, bridging the gap between theoretical knowledge and operative mastery in a way that is engaging, efficient, and aligned with modern competency-based frameworks. While challenges remain, the continued evolution of immersive simulation and AI promises a future where surgical training is more accessible, objective, and effective than ever before.

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