Title: Gamification in Cardiothoracic Surgical Education: Time to Learn More

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Glossary of Abbreviations

AATS: American Association for Thoracic Surgery
ABS: American Board of Surgery
ABSITE: American Board of Surgery In-Training Examination
ACC: American Clinical Congress
ACS: American College of Surgeons
AMSE: Academy of Master Surgical Educators
ASC: Academic Surgical Congress
CC: Clinical Congress
FIT: Fellows In-Training
ITE: In-Training Examination
JCTSE: Joint Council on Thoracic Surgery Education
MKSAP: Medical Knowledge Self-Assessment Program
NLM: National Library of Medicine
SCORE: Surgical Council on Resident Education
STS: Society of Thoracic Surgeons
STSA: Southern Thoracic Surgical Association
TSC: Thoracic Surgery Curriculum
TSDA: Thoracic Surgery Directors Association
TSRA: Thoracic Surgery Residents Association
WU: Washington University in St. Louis

Central Picture Legend:
Theoretical frameworks of gamified learning, student engagement, and game attributes.
Central Message

Current evidence suggests that gamification has the potential to be a highly useful tool for cardiothoracic surgical educators in addition to existing didactic and Socratic methods of instruction.

Perspective Statement

In recent years, gamification has been increasingly incorporated into medical and surgical curricula as an effective companion to traditional teaching methods. Our review of the literature indicates that further implementation of gamification in cardiothoracic surgical training curricula can stimulate learner engagement and improve trainees’ knowledge and skill acquisition.

Keywords: gamification, cardiothoracic surgery, simulation, learner engagement, education

Introduction

Gamification is “the process of adding games or game-like elements to something to encourage participation” and improve performance(1). With the evolution of technology and data-driven approaches to problem-solving, gamification has been implemented in fields including business, marketing, and education(2).

In retail, Starbucks spurs consumer spending through its “My Rewards” system, awarding customers “stars” for every purchase(3). The popular app Duolingo has gamified language learning for over 500 million users through virtual characters and prizes(4). Gamification can be readily adapted to medical education by leveraging the learner’s innate desire for motivation and competition(5).

Gamification shows potential as an adjunct to didactic or Socratic methods(6). Although several studies using gamification have been conducted in medicine, there is a paucity of cardiothoracic literature studying gamification, which may indicate a lack of awareness or
difficult sustainability due to the resources required. To address this knowledge gap, we conducted a review of the literature on gamification in cardiothoracic education to examine its potential as an instructional method in our discipline.

**Materials and methods**

Between 02/26/2023 and 03/30/2023, we conducted a literature search of gamification in medical education using the NLM’s PubMed database. MeSH terms included combinations of: (“gamified” OR “gamification” OR “gamifying”) AND (“surgical” OR “medical” OR “medicine” OR “cardiothoracic” OR “cardiothoracic surgical” OR “robotic”) AND (“education” OR “training” OR “learning”). We identified additional papers using the reference lists of each included paper.

We screened papers by evaluating the title, abstract, and full text. The abstracts of papers (n=52) with relevant titles were reviewed by two authors (AP, BDK) and read in full (n=25).

**Results**

We identified 11 studies describing the use of gamification in teaching medical knowledge and skills to learners ranging from first-year medical students to PGY-7 cardiothoracic trainees. Knowledge-based games focused on examination preparation, while skill-based games encompassed simulation and vascular anastomotic techniques. Most studies included objective and subjective evaluations (Table 1).

**Range of gamification themes in recent medical literature**

Although our primary focus is on surgical education, we provide two papers in non-surgical disciplines that present a framework for understanding gamification.

Twist and Ragdale(7) designed Candy Gland, a board game in which medical students progressed by correctly answering diabetes-related questions. Immediately pre- and post-
intervention—which consisted of a 50-minute session of playing Candy Gland—the 99
participants completed a survey assessing their confidence in diabetes management on a 4-point
Likert scale, and a 10-question test. Test results and self-reported confidence improved, and
students had positive perceptions of the intervention.

In 2018, Dakroub et al(8) evaluated a novel 22-week intervention called the “Cohort Cup.” In a team-based format, 105 medicine residents reviewed high-yield information from the American College of Physicians' MKSAP through quizzes inspired by popular culture. Resident engagement, board review session attendance, and examination pass rates (86% to 97%) increased.

**Effectiveness of game-based interventions in surgical education**

Effectiveness is the degree to which an intervention accomplishes its desired result(9). Most studies focus on trainee knowledge or operative skills as outcomes of interest.

**Effect on knowledge**

Supported by the AATS, JCTSE and TSDA, Mokadam et al(10) explored two competitive games in thoracic surgery curriculums: “Top Gun” and “Jeopardy.” “Jeopardy” was created as an incentive to use the then-new TSC developed by the JCTSE, which was the precursor to the current STS learning management system. The STS currently runs “Jeopardy.” “Jeopardy” began with a screening examination available to all thoracic surgery residents. Contestants’ demographics, TSDA ITE scores, subspecialties and preparation for the contest were recorded. Contestants from the same program combined their scores to form two-person teams. Sixty-eight residents completed the initial examination; the top six teams participated in a well-attended, highly engaging game resembling Jeopardy at the 95th Annual AATS meeting. Traffic to the TSC website increased in response. Although the impact of “Jeopardy” on resident
knowledge was not directly assessed, mean ITE percentile for finalists was 81.8, versus 70.8 for other participants. However, this is likely due to differences in baseline knowledge between finalists and other competitors.

In 2021, Hancock et al (11) designed a Jeopardy-style game for general surgery residents. Questions were adapted from SCORE portal questions and increased in difficulty along with point values. Jeopardy sessions assessed four specific categories on the ABSITE. Residents’ ABSITE scores in these domains increased significantly from 65.9 to 70.4 percent. Overall program ABSITE scores increased from the 41st to 47th percentile.

McAuliffe et al (12) conducted a gamification study where general surgery residents were assigned to teams through a “draft system.” Up to 54 residents participated each year from 2017-19. Teams earned “points” through team-based activities and individual resident performance, appraised through knowledge and patient care. The highest performers earned prizes. Residents’ median ABSITE percentile improved from 28 to 43, and first-time ABS qualifying exam pass rates increased from 73% to 100%.

**Effect on surgical skill**

Moran et al (13) designed a robotic simulation league for urology residents. Fifteen residents were divided into four teams and taught the basics of simulator use and ergonomics. Each round, participants completed three exercises scored from 0 to 100, accounting for efficiency metrics and penalties. There was a notable improvement in resident skills with a median score increase of 19 points from their first attempt to their best one.

Similarly, El-Beheiry et al (14) assessed gamification of laparoscopic simulation among 25 first-year surgical residents in 2014. Authors posted biweekly leaderboards with the fastest peg transfer times. The class of 2013 was a control group. Despite similar simulator usage times,
residents in the competition group outperformed the control and demonstrated better task efficiency.

“Top Gun,” a game explored by Enter et al (15) in 2013, measured operative skill through simulation of coronary anastomoses. Cardiothoracic residents first submitted a baseline performance of an end-to-side coronary anastomosis using a TSDA-provided simulator. After six weeks of mentored training, residents submitted a final performance of an anastomosis. The top five final performers competed live at the 93rd annual AATS meeting. Average anastomosis scores (range 0-5) improved from 3.24 to 4.01, and average times decreased (670 versus 544 seconds). Initially, the top 50% of residents scored significantly higher than the bottom 50% (3.71 versus 2.75), but on the final submission, there was no significant score difference between the groups. In a follow-up study by Mokadam et al (10), 43 baseline videos and 34 final videos were submitted between 2013 and 2015. Residents were assessed in 13 categories, and mean scores improved from baseline to final submission (Figure 1).

Lin et al (16) investigated the validity of a novel game called SICKO (Surgical Improvement of Clinical Knowledge Ops) to assess surgical decision-making skills. SICKO requires players to make accurate operative decisions, earning and losing points and receiving feedback at key moments. Forty-nine subjects, including 11 novices, 27 junior residents, nine senior residents, and two experts, played SICKO. Mean scores increased with participant skill, confirming SICKO’s validity as a training and assessment platform.

Hockman et al (17) compared clinical outcomes between hip fracture patients operated on by two groups of orthopedic surgery residents. Residents in the experimental group utilized both standard and gamification techniques during 34 operations, while residents in the control solely implemented standard techniques in 114 operations. Operating time (45.6 versus 57.1 minutes)
and fluoroscopy time were shorter in the experimental group. Other clinical outcomes were similar.

**Feasibility of implementation**

Numerous studies also discussed a given intervention’s feasibility, or the ease with which it is implemented(18). Authors described the resources required and how they were allocated by stakeholders.

“Top Gun” (15)(10) was made possible through collaboration between the TSDA, AATS, JCTSE, and Ethicon, Inc. Ethicon funded the competition via an unrestricted educational grant. Judges were recruited to score anastomosis videos, and voluntary faculty mentored trainees. The JCTSE, TSRA, STS, and AATS spread awareness of the “Jeopardy” competition by Mokadam et al, provided the learning management system, and hosted the live final competition. Lin et al(16) were supported by a Stanford Continuing Medical Education grant in creating SICKO.

Conversely, other studies used existing platforms. Moran et al(13) utilized the da Vinci Skills Simulator for a robotic surgery league, while El-Beheiry et al(14) employed the widely-available LAP Mentor™ (Simbionix Ltd, Israel) laparoscopic simulator. Finally, several authors provided nominal participation fees to promote engagement(12).

**Acceptability and engagement**

Acceptability encompasses student response to an intervention, its impact on engagement, and changes an intervention inspired in student habits.

Most participants in the “Top Gun” study agreed that their experience was valuable and that simulation can improve surgical skills (15). In a post-questionnaire, participants agreed that Jeopardy encouraged studying, stimulated interest, and that sessions were engaging and increased knowledge retention(11). Following the implementation of a gamified curriculum by
McAuliffe et al. (12), resident engagement increased, and satisfaction improved from 65\% to 88\%. Similarly, participants rated SICKO’s usability and content highly (16). Participants in a robotic surgery simulation league reported increased confidence in their robotic skills and operative autonomy (13).

Multiple studies examined time and effort devoted by trainees toward gamification tasks. Participants in the “Jeopardy” game reported that they would prepare an additional 9.9 hours per week on average if they qualified for the final competition (10). During a robotic surgery simulation league (13), median monthly simulator practice increased. Participants in the competition group of the study by El-Beheiry et al. (14) were more likely to continue voluntarily using the simulator after the study.

Several studies implemented team-based gamification interventions. Participants in the study by McAuliffe et al. (12) strongly (83\%) agreed that being on a team inspired them to perform better. Moran et al. (13) concluded that team-based games made participation less burdensome and built camaraderie. Lack of time and difficulty accessing simulators were the biggest factors limiting trainees’ simulator use (13, 19).

**Discussion**

Gamification can positively influence trainee knowledge and skills in cardiothoracic surgical education. Incorporating gamification elements into surgical curricula utilizing user-friendly technology is feasible, and learner perceptions are overwhelmingly positive.

Gamification augments subjects’ intrinsic motivation—their internal desire to acquire knowledge—through extrinsic motivation—acquisition of knowledge in pursuit of a reward (20). Neurotransmitters including dopamine, oxytocin, and serotonin, which have been linked to learning in human and animal studies (21), are released when playing games, establishing a
The benefits of gamification across levels of education and disciplines translate into measurable short- and long-term improvements in knowledge retention and practical skills, increasing competence (23-25). Attributes of effective gamification are shown in Figure 2. Notably, improvements in engagement from gamification extend to educators, which could encourage more faculty participation in gamification programs (26).

It is difficult to conclusively prove that gamification is “more effective” than traditional forms of education without widespread adoption. However, a systematic review of gamification across health education by van Gaalen et al (27) confirms that gamification to improve learning outcomes is promising and warrants further research. Bigdeli et al (28) note that future gamification research should target specific learning theories, including behaviorism, cognitivism, constructivism, and adult learning theory (29). Gamification may also augment competence-based education (CBE), which enables increased individualization by allowing students to proceed at their own pace. At WU, surgical faculty have implemented a robotic skills curriculum using the da Vinci Skills Simulator (Intuitive Surgical, Inc.) and training modules to assess surgical competence. Completion of the curriculum resulted in improved operative performance (30). While simulator-based games may be useful in measuring resident performance and personalizing training, gamification by itself is not CBE, which encompasses effective assessment metrics, feedback loops, and a well-defined, holistic curriculum. Certain elements of cardiothoracic education make our field ideally suited for adopting gamification. Firstly, strong team structure is critical to clinical care and resident training in cardiothoracic surgery; training programs are optimal for integrating team-based gamification in their curricula (12, 13). Secondly, cardiothoracic surgery requires high precision and dexterity, which
can be enhanced through simulation-based games\(^{(10, 13, 14)}\). Thirdly, the relatively small cohort of cardiothoracic trainees nationwide facilitates large-scale competition, such as “Top Gun” and “Jeopardy”\(^{(10)}\), which cater to the competitive nature of residents. Finally, cardiothoracic education has the strong support of national bodies, including the AATS and STS—who organized and publicized “Jeopardy”—and the TSDA, which distributed the anastomosis model used for Top Gun with support from Medtronic; the model was designed by and is now available for purchase from The Chamberlain Group \(^{(31)(10)}\). ACC FIT also hosts a “Jeopardy”-style competition. The ACS’ annual CC hosts gamification-based programs—“Jeopardy” and a skills competition. Collaboration between thoracic surgical organizations and the ACS AMSE can enhance the visibility and impact of gamification efforts. Additionally, Intuitive Surgical, Inc. has designed “SimNow” games, used at STS’21, AATS’21 and annually at the ACS CC, ASC, and SAGES’23. While currently there is no direct industry support for the “Top Gun” competition, this remains an area for discussion. Partnering with industry for grants and co-development of platforms remains a possibility, although this would require keeping resident education neutral without influence from industry, while providing material support. Philanthropy and development of games through unrestricted/unconditional grants may be an alternative solution.

Operationalizing gamification requires action at the program, regional, and national levels. At the program level, gamification can be incorporated into cardiothoracic curricula through relatively inexpensive means, utilizing low-cost simulators such as the da Vinci Skills Simulator or by developing new, innovative gameboards\(^{(7, 10)}\) that may teach technical and cognitive skills including cardiopulmonary bypass management, extracorporeal support, and single lung ventilation\(^{(13)}\). Institutions may share human and material resources to reduce costs.
Furthermore, higher-tech models including KindHeart™ (KindHeart Inc.) simulators can be made available to programs to teach minimally-invasive lung resection(32). Objective methods of assessing performance using such models already exist(33). Programs may also augment existing simulation-based skill training. Feins et al and Hussein et al have shown that simulation training in cardiothoracic surgery translates into operative improvements(34, 35). Nationally, resources and experience from individual organizations could be systematically shared to construct a better model for implementing gamification. Additionally, the annual “Educate the Educators” (EtE) course for surgical educators provided academic cardiothoracic surgeons the fundamentals of teaching skills and curriculum development; between 2010 and 2014, 97% of United States cardiothoracic surgery training programs were represented. Widely accepted as a useful experience, faculty development components of EtE have been incorporated into the TSDA and may be an effective way to introduce gamification and simulation to program directors(36).

Gamification in cardiothoracic education carries other benefits. Adding gamification programs to medical student clerkship may enhance students’ interest in pursuing cardiothoracic surgery(37-40). Incorporating elements of gamification into the national online curriculum for thoracic surgical trainees may augment trainee engagement and further improve knowledge(41). Specifically, we suggest that local chapters of the “Top Gun” competition be instituted for cardiothoracic surgical residents and even mid- and senior-level general surgical trainees to promote development of fine suturing skills(10). Similarly, in general thoracic surgery, robotic simulation models for lung resection can be easily gamified at the program level through small-scale competition(13). In the age of virtual communication and competition, these two “games” can readily be expanded to regional and national levels.
Gamification in cardiothoracic surgical education shows promising preliminary results.

Introducing simulation and gamification can leverage the natural competitiveness of surgical trainees. As we gain insight into maximizing gamification’s potential benefits, we anticipate greater incorporation of gamification into cardiothoracic training curricula.

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Figure 2: Relationship between theoretical frameworks of gamified learning, student engagement, and game attributes. Adapted from Rivera and Garden(42).
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