AMERICAN COLLEGE OF
Medical Quality

How Many Lives Will You Save? A Mixed Methods Evaluation of a Novel, Online Game for Patient Safety and Quality Improvement Education

Gabriela Ruiz Colón, BA[1], Kambria Evans, MEd MA LMFT[2], Mia Kanzawa, MD[3], Anuradha Phadke, MD[1], Laurence Katznelson, MD[1], and Lisa Shieh, MD PhD[1]

Abstract

Medical trainees have limited knowledge of quality improvement and patient safety concepts. The authors developed a free quality improvement/patient safety educational game entitled Safety Quest (SQ). However, 1803 undergraduate medical trainees, graduate medical trainees, and continuing medical education learners globally completed at least 1 level of SQ. Pre- and post-SQ knowledge and satisfaction were assessed among continuing medical education learners. Thematic analysis of feedback given by trainees was conducted. Among graduate medical trainees, SQ outranked other learning modalities. Three content areas emerged from feedback: engagement, ease of use, and effectiveness; 87% of comments addressing engagement were positive. After completing SQ, 98.6% of learners passed the post-test, versus 59.2% for the pretest ($P < 0.0001$). Ninety-three percent of learners agreed that SQ was engaging and interactive, and 92% believed it contributed to their professional growth. With an increased need for educational curricula to be delivered virtually, gamification emerges as a unique strategy that learners praise as engaging and effective.

Keywords:

graduate medical education, undergraduate medical education, patient safety, quality improvement, gamification

Introduction

A recent meta-analysis has revealed that at least 1 in 20 patients has been affected by preventable patient harm in medical care settings, with approximately 12% of these incidents resulting in permanent disability or patient death.[1] As the widespread nature of medical errors has become recognized, the Accreditation Council for Graduate Medical Education (ACGME) incorporated quality improvement (QI) and patient safety (PS) into the Clinical Learning Environment Review (CLER) program, a program used to provide feedback to institutions as they seek to optimize both trainee experience and patient care.[2] At many institutions, QI/PS curricula are delivered through small group sessions, lectures, conferences, online modules, and videos.[3] Despite this increased emphasis on QI/PS education, graduate medical education (GME) trainees continue to demonstrate limited knowledge of basic QI/PS concepts in the majority of clinical learning environments.[3,4]

Barriers to the successful implementation of these educational initiatives include a lack of learner engagement and competing time commitments.[5] Engagement in discussions and lectures may be limited by a lack of application of learned concepts and clinical relevance; projects are limited by learner and faculty time commitments and resources.[3,5] At the authors' institution, gamification has been previously used as a strategy to promote learner engagement and improve knowledge. In 2011, Septris, a gamified course aiming to teach evidence-based practices for sepsis management, was developed and demonstrated a significant increase in recognition and management of sepsis among users.[6] These findings are consistent with other studies that have demonstrated that gamification enhances learner engagement, specifically

[1]Department of Medicine, Stanford University School of Medicine, Palo Alto, CA
[2]Zero Disturbance, San Jose, CA
[3]Department of Medicine, Kaiser Permanente, San Francisco, CA

Corresponding Author:
Lisa Shieh, MD PhD, Department of Medicine, Stanford University School of Medicine, 500 Pasteur Drive Palo Alto, CA 94304. Email: lshieh@stanford.edu

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.ajmqonline.com).

American College of Medical Quality XXX Vol. XXX(00) 00-00

DOI: 10.1097/JMQ.0000000000000153

among medical trainees.[7] Gamification allows for immediate application of learned concepts and feedback, as well as the creation of clinical scenarios to ensure clinical relevance. To that end, the team developed a free QI/PS educational game entitled Safety Quest (SQ), with the objective of enhancing learner knowledge of QI/PS topics in a flexible and accessible manner. The online delivery of material grants learners the flexibility to review material at their own pace while promoting engagement and perceived importance of the material, which has been noted in other PS games.[8]

In this article, the authors describe the results from the launch of SQ. They assess the impact of the deployment on learner knowledge and satisfaction on a large group of undergraduate medical education (UME) and GME trainees, as well as continuing medical education (CME) learners globally.

Methods

SQ Development, Pilots, and Launch

The team developed a free QI/PS educational game entitled SQ. The SQ curriculum was developed based on the ACGME's CLER program, which incorporates health care quality and PS standards. The core curriculum is structured as 4 case-based, progressive levels based on subject matter in procedural and nonprocedural fields. The levels are structured as Level 1: introduction to safety and QI basics; Level 2: moving beyond the basics; Level 3: implementing QI; and Level 4: mastering QI. The objectives of each level are found in Table 1. SQ was developed in 2015 and is freely available to play in English at https://safetyquest.stanford.edu/. All technical development was done by a third party, Studio Cypher[9]; the authors conceived of SQ and determined learning objectives, curriculum content, and game mechanics. SQ is a Stanford University-sponsored program and is hosted by the CME program. As part of the Stanford educational community, there is no additional charge to host this game or for others at other institutions to use it.

Two proof-of-concept pilot studies were conducted prior to this study. In the first, 47 internal medicine interns were randomized to play SQ (n = 26, test group) or Septris (n = 19, control group). Individuals who played Septris showed no improvement in a knowledge assessment focused on QI and PS topics; however, SQ players had a significant increase in QI and PS knowledge after playing.[6] In the second pilot, 45 internal medicine interns were found to have significant improvements in QI and PS knowledge after playing SQ.

Table 1. SQ Curriculum Content, Based on the ACGME's CLER.

Level 1: Introduction to safety and QI basics	**Level 2:** Moving beyond the basics	**Level 3:** Implementing QI	**Level 4:** Mastering QI
Integrate best practice patient safety and goals of care (GOC) communication techniques (eg, IPASS handoffs, SBAR communication, stop the line, call for help early, debriefing, GOC documentation) into practice with teams to reduce the risk of adverse events and increase patient safety	Analyze when systematic learning from error is the best response to ensuring patient safety (eg, 5 Whys, Root Cause Analysis, Pareto Curve, Fishbone/Ishikawa Diagram) to reduce the risk of adverse events and increase patient safety.	Apply advanced QI tools such as failure modes effect analysis and key concepts of stakeholder analysis, A3 key drivers and project sustainability to improve the quality of care for your patients	Utilize Lean principles such as 5 Ss and reducing/eliminating waste (3 Ms) to improve quality of care for your patients
Utilize principles from the Joint Commission's National Patient Safety Goals to reduce the risk of adverse events and increase patient safety	Utilize best practices such as medicine reconciliation, order sets and checklists and QI tools such as process mapping and systems approach principles to improve the quality of care for your patients.	Perform time-out/Universal Protocol to prevent sentinel events/never events (eg, wrong site, wrong procedure, and wrong person surgery, retained foreign objects) consistent with best practices to reduce the risk of adverse events and increase patient safety and consistent with the Joint Commission's National Patient Safety Goals	Analyze quality improvement data using statistical process control
Apply QI tools and concepts such as plan-do-study-act, A3, high reliability, and the "Swiss Cheese" model to improve the quality of care for your patients	Learn key safety and teamwork concepts to promote a positive safety culture	Report errors and near misses (event reporting) and disclose errors to patients and their families (error disclosure) when you and your team have been involved in or witnessed such an event	Apply high value care principles to your practice

Abbreviations: IPASS, Illness Severity, Patient Summary, Action List, Situation Awareness and Contingency Planning, Synthesis by Receiver; QI, quality improvement; SBAR, Situation, Background, Assessment, Recommendation.

Setting and Participants

SQ was incorporated into the curriculum for medical residents and fellows at a single institution in June 2018. Medical students and GME trainees enrolled in QI electives were also eligible to play SQ. SQ was made available for CME learners globally. SQ information was advertised through a promotional video, emails to other institutions, and flyers. The institutional review board waived review for this study based on its classification as quality improvement.

Impact Assessment

The team assessed the impact of SQ on 2 levels: learner satisfaction (Kirkpatrick's level 1) and changes in learner attitudes and measures of learner knowledge (Kirkpatrick's level 2). To be included in the assessment, GME trainees must have completed at least 1 level of SQ. To assess the satisfaction of GME trainees, learners were provided with an online, anonymous survey soliciting attitudes toward the game. The survey asked learners to rank the game in comparison to other modalities (videos, web modules, articles, and slide presentations) and provided space to share anonymous, free-text comments and feedback regarding SQ. To assess knowledge, CME learners took a test before beginning SQ and completed a post-game test and satisfaction survey. When taking the quiz, all questions were weighted equally, and each was worth 1 point. The assessment questions by level can be found in Supplemental Digital Content, available at http://links.lww.com/AJMQ/A103.

Data Analysis

Demographics, satisfaction rates of CME learners, preferences of medical trainees, and percent of all learners passing their pre- and post-test assessments were assessed using Fisher exact tests and Wilcoxon rank sum tests. All analysis was conducted using GraphPad Prism Version 9 (San Diego, CA).[10]

GME trainees provided free-text feedback on SQ, which was analyzed through content and thematic analysis following qualitative methodology guidelines.[11–13] The objective of this analysis was to determine themes (content areas) arising from participants' feedback to understand the game and learning attributes most important to participants. Content areas were determined through a manual review of free-text feedback and iterative discussions among 3 raters, all of which were trained in qualitative methodology. Minor content areas were initially identified and then consolidated into 3 major content areas. After the determination of primary content areas, each comment was coded by a primary rater as containing overall positive, neutral, or negative sentiment and evaluated for representation of content areas. In addition to the overall rating, comments were coded as positive or negative for each content area addressed. A second rater coded 20% of the comments. The 2 raters discussed participant perspective codes a priori, with positive codes being those that offered praise to SQ or deemed it to be helpful for their educational development, whereas negative codes were assigned to comments that included criticisms of SQ. Interrater variability between the primary rater and the second rater was assessed with Cohen's kappa. Themes were derived from comments that were positive in one content area and negative in another, thus resulting in 6 groups of comments. Two raters individually identified themes from each pool of comments and then reconciled them to produce a final set of themes.

Results

Participants

In 2018, 1470 GME trainees and 65 UME trainees completed at least 1 level of SQ. A total of 374 CME learners participated from 2019 to 2020. GME learners came from 22 specialties, and the internal medicine (313) and pediatrics (211) programs had the most GME trainees who completed 1 level of SQ (Table 2). Most CME learners came from the United States (190), India (22), and the United Kingdom (15) (Table 2). Overall, 59% of CME learners resided in North America, 19% in Asia, 11% in Europe, 6% in Africa, 4% in South America, and 1% in Oceania. CME learners included physicians (51%), nonphysicians (15%), nurses (3%), and allied health professionals (3%). The majority of the remaining 28% comprised of individuals who did not list their role/position and individuals who worked in industry (1%).

Medical Trainees' Outcomes

Forty-five percent of GME trainees ranked SQ first in their preferred learning modality, and 48% of UME trainees ranked SQ first. Video was the second most preferred learning modality among GME (40%) and UME trainees (31%). Online modules, articles, and presentations were the least preferred learning modalities.

Sixty-seven percent of GME trainees provided free-text comments. Only 8% of UME trainees left feedback, so they were excluded from the thematic analysis. Free-text responses ranged from 1 to 84 words in length, with an average of 8 words per response. Overall, 72% of comments were positive, 6% neutral, and 22% negative. Cohen's kappa for rating the overall sentiment of comments was 0.90. Initially, 8 minor content areas were identified (enjoyment, learning modality, interface, clarity of content, level of content, clinical relevance, efficiency, and effectiveness) and narrowed down to 3 major content areas: engagement, ease of use, and effectiveness. Of

Table 2. Demographics of GME Trainees and CME Learners Playing SQ.

Graduated medical education trainees	
Specialty	N (%)
Internal medicine	313 (21.3%)
Pediatrics	211 (14.4%)
Anesthesia	139 (9.5%)
Radiology	93 (6.3%)
Psychiatry	92 (6.3%)
Pathology	70 (4.8%)
Orthopedic surgery	67 (4.6%)
General surgery	64 (4.4%)
Emergency medicine	58 (3.9%)
Neurology	58 (3.9%)
Obstetrics and gynecology	38 (2.6%)
Family medicine	31 (2.1%)
Otolaryngology	29 (2.0%)
Dermatology	25 (1.7%)
Plastic surgery	25 (1.7%)
Neurosurgery	21 (1.4%)
Radiation oncology	21 (1.4%)
Urology	20 (1.4%)
Thoracic surgery	17 (1.2%)
Ophthalmology	16 (1.1%)
Vascular surgery	14 (1.0%)
Medical genetics	2 (0.1%)
Program not listed	46 (3.1%)
Total	1470
Continuing medical education learners	
Continent and countries	N (%)
North America	220 (58.8%)
United States	190
Canada	14
Mexico	9
Other	7
Europe	40 (10.7%)
United Kingdom	15
Greece	4
Spain	4
Other	17
Africa	22 (5.8%)
Egypt	13
Sudan	2
Other	7
Asia	71 (19.0%)
India	22
Saudi Arabia	14
Pakistan	6
Other	29
South America	16 (4.2%)
Brazil	10
Argentina	2
Colombia	2
Other	2
Oceania	3 (0.8%)
Australia	2
New Zealand	1
Unlisted	2 (0.5%)
Total	374

all comments, 52% related to engagement, 32% on ease of use, and 15% on effectiveness. Eighty-seven percent of comments addressing engagement were positive, whereas 52% and 41% of comments addressing effectiveness and ease of use were positive, respectively (**Figure 1**).

Forty-one comments out of the total 918 (4.5%) contained comments that were positive in one content area and negative in another (**Figure 2**). These comments tended to be longer and contained more depth of information (22 words on average). The theme that was most prevalent was that the format was engaging (n = 31); however, the content was either too simplistic or examples were not relevant to everyone's specialty.

CME Learners' Outcomes

Among CME learners, 59.2% passed the pretest; upon completion of SQ, 98.6% of CME learners passed the post-test ($P < 0.0001$). Regarding satisfaction, 93% of CME learners agreed or strongly agreed that SQ was engaging and interactive, 93% thought this CME improved their knowledge, and 92% thought it contributed to their professional growth (Table 3). When asked to rate the quality of the content on a scale of 1 to 5, with 1 being the worst and 5 being the best, 87% rated SQ a 4 or 5 in quality, 87% rated SQ a 4 or 5 regarding the delivery and effectiveness of the content, and finally, 85% rated SQ a 4 or 5 regarding the value of the topic and content.

Discussion

To the authors' knowledge, SQ is the first, free, online QI and PS game available. In this article, the authors investigated the acceptability and preference of SQ among UME and GME trainees, and CME learners. Among trainees, they demonstrate that SQ outranked other learning modalities for PS and quality education, and on free-text feedback, many praised it for being engaging. Among 374 global CME learners, the team demonstrated a statistically significant increase in the percentage of learners passing the course assessment, with nearly 90% of users believing it was engaging and interactive, contributed to their professional growth, and/ or improved their knowledge.

This study builds upon existing literature describing strategies to educate medical trainees and other health care professionals on the principles of QI and PS. A review published in 2020 demonstrated a rapid transition during the COVID-19 pandemic to virtual education modalities, as social distancing orders rendered in-person didactics, workshops, and coaching sessions unfeasible.[14] In that review, the authors identified 19 studies published between 2015 and 2020 describing QI education interventions. Of those, only 6 were fully online; the remaining had both online and in-person components. The authors found that online modules, webinars, emails, calls, and video lessons were among the most common tools used to deliver content. Moreover, the authors

Content Area		Representative Comment
Engagement	+	"I really liked the 'video-game'-like modality. It makes it fun and quick to complete. the graphics were very good too. I think all modules (including the HIPPAA and legal ones) should adopt this feature."
	-	"I appreciate the effort to make the learning interactive. While it falls short of being stimulating and entertaining, compared to other typical methods of online education, it is clearly a step forward. I commend the Safety Quest team on their efforts to move online education in this direction."
Ease of Use	+	"The tutorial itself took some adjusting to but once you understand it, its easy to use. I liked that it was interactive"
	-	"Difficult to navigate. Takes more time to learn to use the simulation than to learn"
Effectiveness	+	"The game was straightforward and required evaluation of the scenarios in a way which multiple choice questions alone do not. This helps to reinforce concepts as we are asked to apply them in a different way"
	-	"The fact that safety quest is in a game format does not help me learn patient safety more effectively than, say, a simple learning module"

Figure 1. Content areas emerging from qualitative analysis of free-text responses.

Theme			Representative comment
Format was engaging; however, content was either too simplistic or examples were not relevant to my specialty.			• "Good as an interactive introduction, but not in-depth enough for someone starting or currently managing a QI project."
Engagement +	Effectiveness –	n = 22	
Content was useful, but the gaming modality did not add value			• "Didn't really find the "game" itself was that helpful. The directed questions were more educational"
Effectiveness +	Engagement –	n = 5	
Enjoyed the interactive nature, but the game and interface were not intuitive			• "A little slow and cumbersome but the interactive format was fun and helpful!"
Engagement +	Ease of Use –	n = 9	
Appreciated the content, but the interface was difficult to use			• "It was not very user-friendly, but I appreciated the lessons it taught me."
Effectiveness +	Ease of Use –	n = 5	

Figure 2. Thematic analysis of free-text comments containing more than one content area.

note that the majority of programs leveraged the existing online education modules published by the Institute of Healthcare Improvement instead of designing their own curricula.[15] None of the studies identified in this review discussed the development of a game as a tool for teaching, though 1 study did use elements of gamification to increase participation.[14] In that randomized control trial by Scales et

Table 3. CME Learners' Satisfaction With SQ Material.

	Covered content useful for my practice	Contributed to my professional growth	Was relevant to my current scope of practice	Was engaging and interactive	This CME improved my knowledge
Strongly agree	225	213	216	235	230
Agree	126	146	138	127	130
Neutral	34	25	28	20	27
Disagree	2	2	4	5	1
Strongly disagree	2	3	3	2	1
% Agree or strongly agree	90%	92%	91%	93%	93%

al,[15] residents were emailed interactive QI-focused questions; those in the intervention arm had a team assignment with aliases, team leaderboards, and individual leaderboards. The authors demonstrated that participants in the intervention arm who had gamification features had more questions attempted and had a lower average response time, showing overall greater participation, and demonstrating that gamification can increase the participation and engagement of learners.[17]

This study builds on the study by Scales et al demonstrating the value of gamification for not only participation but also knowledge acquisition of CME learners. Despite the ACGME's incorporation of QI and PS education into the CLER and the Association of American Medical Colleges endorsing formal QI and PS education in medical students, there remains a significant gap in knowledge among medical trainees. For instance, in 1 study of 450 medical students at a US medical school, while 79% of participants claimed prior education in QI and PS, on average, participants answered 56% and 58% of questions surrounding PS and QI correctly, respectively.[18] Similar findings have been observed among graduate medical trainees, where at baseline, before a QI intervention, many cite discomfort in applying QI principles or are not able to correctly answer questions regarding the ACGME's core competencies.[3] One systematic review by Wong and colleagues described barriers to quality and PS education among medical trainees, including low enthusiasm for the curriculum, limited time (eg, competing educational demands), and limited resources (eg, having expert teaching faculty for the material).[5] Thus, approaches to education in these topics need to keep such barriers in consideration.

Gamification emerges as a unique strategy to address such barriers identified by Wong et al[5] Beyond promoting learning engagement and motivation, the education literature has demonstrated that gamification can improve learning achievement.[19] By implementing these elements of gamification, SQ addresses the commonly cited issues of teaching QI and PS. These results demonstrate wide participation and buy-in from trainees (n = 1470 GME and n = 65 UME) in the gamification approach, and free-text feedback commending SQ's engaging features. Another advantage of SQ is its accessibility. As a fully online, standalone game experience, users from around the world can play for a certificate or CME credit. Additionally, SQ is scalable. It may be quickly shared and accessed by anyone who has internet access at any time; there is no need to coordinate start time with other trainees or to identify expert faculty to teach the content. This format makes it an especially important educational modality in the era of COVID-19, as the need for digital educational tools has become apparent.[20] Moreover, while SQ can be used as an individual tool, it may also be integrated into broader quality and PS education efforts by training programs, units, and institutions.

Finally, another advantage of SQ is that it places users in a decision-making capacity, promoting active learning. Many of the educational strategies reported in the literature rely on passive learning—for instance teaching trainees about Plan-Do-Study-Act cycles by lecturing on the acronym or sharing case vignettes of successful initiatives. SQ, on the other hand, places the learner in an active position to appraise a clinical situation, evaluate options, make decisions, and ultimately receive immediate feedback. Prior literature has demonstrated active learning to be more efficient in promoting academic achievement and long-term material retention, supporting the team's goal to enhance active learning.[21,22] One challenge to developing tools like SQ is the cost of developing the game.

Limitations

This study is not without limitations. First, knowledge obtained was only measured by CME learners completing pre- and post-test assessments and not among medical trainees. Given the ACGME's incorporation of QI and PS into CLER, it would be useful

to understand if this curriculum improved trainees' knowledge base. Another limitation comes from the analysis of free-text feedback of SQ from GME trainees. This analysis required raters to interpret the text to produce codes and could be influenced by individual rater bias. To mitigate this, raters were not involved in the development of SQ, and a Cohen's kappa was calculated, which indicated strong agreement between raters. In addition, the authors do not have access to granular data on individuals' scores in the pre/post-tests, rather "pass" or "not pass." Further, granular data would allow them to better capture the impact of SQ on knowledge acquisition. Moreover, it would be interesting to assess long-term outcomes, including QI knowledge and engagement in QI initiatives. Another limitation is that the SQ launch and survey were conducted in the pre-COVID-19 pandemic era. It would be interesting to understand if gamification continued to be an effective engagement strategy throughout the height of the COVID-19 pandemic when the majority of medical trainee education (eg, morning report, noon conference), meetings, and some outpatient care remained virtual.

Conclusion

SQ is an online, gamified approach to teach quality and PS to all levels of medical learners. Medical trainees preferred SQ to other learning modalities, and most lauded it for being engaging. The post-test pass rate was statistically significantly greater among CME learners after completing SQ, and most believe it was beneficial for their professional growth. Collectively, the authors demonstrate that gamification promotes engagement in learning critical information by allowing users to apply the critical thinking skills of PS and QI that are required to reduce medical errors in clinical practice. Finally, a scalable, in situ simulation tool such as SQ allows for greater flexibility for learners to complete the curriculum and allows for national and international dissemination.

Acknowledgments

The authors would like to acknowledge Studio Cypher for technical design and development and the Stanford Medicine Office of Continuing Medical Education.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

Funding

Stanford Health Care provided funding for Safety Quest game development. GRC received funding from the Society of Hospital Medicine's Physicians in Training Grant to present this work at SHM Annual Meeting in Spring 2022.

Reprint requests

Please send reprint requests to Dr. Lisa Shieh, lshieh@stanford.edu

Previous Presentations

Portions of this study were previously presented at the Society of Hospital Medicine's Annual Meeting in Spring 2022.

Author Contributions

Drs Evans, Phadke, Katznelson, and Shieh: Conception of Safety Quest game; Ruiz Colón and Kanzawa: Execution of analysis and generation of figures; Ruiz Colón and Evans: Drafting of article; All authors: Critical review of the article.

References

1. Panagioti M, Khan K, Keers RN, et al. Prevalence, severity, and nature of preventable patient harm across medical care settings: systematic review and meta-analysis. *BMJ*. 2019;366:l4185.
2. *CLER*. Accessed September 21, 2023. https://www.acgme.org/initiatives/clinical-learning-environment-review-cler/
3. Kirkman MA, Sevdalis N, Arora S, et al. The outcomes of recent patient safety education interventions for trainee physicians and medical students: a systematic review. *BMJ Open*. 2015;5:e007705.
4. Koh NJ, Wagner R, Newton RC, et al; CLER Program. Detailed findings from the CLER national report of findings 2018. *J Grad Med Educ*. 2018;10:49–68.
5. Wong BM, Etchells EE, Kuper A, et al. Teaching quality improvement and patient safety to trainees: a systematic review. *Acad Med*. 2010;85:1425–1439.
6. Evans KH, Daines W, Tsui J, et al. Septris: a novel, mobile, online, simulation game that improves sepsis recognition and management. *Acad Med*. 2015;90:180–184.
7. Nevin CR, Westfall AO, Rodriguez JM, et al. Gamification as a tool for enhancing graduate medical education. *Postgrad Med J*. 2014;90:685–693.
8. *Finding the "QR" to Patient Safety: Applying Gamification to Incorporate Patient Safety Priorities Through a Simulated "Escape Room" Experience*. PubMed. Accessed January 22, 2023. https://pubmed.ncbi.nlm.nih.gov/31007972/

9. Studio Cypher. Studio Cypher. Accessed September 21, 2023. https://studiocypher.com
10. *Home - GraphPad*. Accessed May 31, 2021. https://www.graphpad.com/
11. Elo S, Kyngäs H. The qualitative content analysis process. *J Adv Nurs*. 2008;62:107–115.
12. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006;3:77–101.
13. O'Brien BC, Harris IB, Beckman TJ, et al. Standards for reporting qualitative research: a synthesis of recommendations. *Acad Med*. 2014;89:1245–1251.
14. Khurshid Z, De Brún A, Moore G, et al. Virtual adaptation of traditional healthcare quality improvement training in response to COVID-19: a rapid narrative review. *Hum Resour Health*. 2020;18:81.
15. *Get Started with the IHI Open School*. IHI - Institute for Healthcare Improvement. Accessed February 2, 2023. https://www.ihi.org:443/education/ihi-open-school/Pages/default.aspx
16. Scales CD, Moin T, Fink A, et al. A randomized, controlled trial of team-based competition to increase learner participation in quality-improvement education. *Int J Qual Health Care*. 2016;28:227–32.
17. *Randomized, controlled trial of team-based competition to increase learner participation in quality-improvement education*. International Journal for Quality in Health Care. Oxford Academic. Accessed January 22, 2023. https://academic-oup-com.stanford.idm.oclc.org/intqhc/article/28/2/227/1750620
18. Blasiak R, Stokes C, Meyerhoff K, et al. A cross-sectional study of medical students' knowledge of patient safety and quality improvement. *N C Med J*. 2014;75:15–20.
19. Zainuddin Z, Chu SKW, Shujahat M, et al. The impact of gamification on learning and instruction: a systematic review of empirical evidence. *Educ Res Rev*. 2020;30:100326.
20. Cronin JA, Saha A, Bhattarai S, et al. Quality improvement education in the era of COVID-19: a pivot toward virtual education. *Pediatr Qual Saf*. 2021;6:e418.
21. Prince M. Does active learning work? a review of the research. *J Eng Educ*. 2004;93:223–231.
22. Michel N, Cater JJ III, Varela O. Active versus passive teaching styles: an empirical study of student learning outcomes. *Hum Resour Dev Q*. 2009;20:397–418.