Article

A randomized, controlled trial of team-based competition to increase learner participation in quality-improvement education

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Abstract

Objective: Several barriers challenge resident engagement in learning quality improvement (QI). We investigated whether the incorporation of team-based game mechanics into an evidence-based online learning platform could increase resident participation in a QI curriculum.
Design: Randomized, controlled trial.
Setting: Tertiary-care medical center residency training programs.
Participants: Resident physicians ($n = 422$) from nine training programs (anesthesia, emergency medicine, family medicine, internal medicine, ophthalmology, orthopedics, pediatrics, psychiatry and general surgery) randomly allocated to a team competition environment ($n = 200$) or the control group ($n = 222$).
Intervention: Specialty-based team assignment with leaderboards to foster competition, and alias assignment to de-identify individual participants.
Main Outcome Measures: Participation in online learning, as measured by percentage of questions attempted (primary outcome) and additional secondary measures of engagement (i.e. response time). Changes in participation measures over time between groups were assessed with a repeated measures ANOVA framework.
Results: Residents in the intervention arm demonstrated greater participation than the control group. The percentage of questions attempted at least once was greater in the competition group (79% [SD ± 32] versus control, 68% [SD ± 37], $P = 0.03$). Median response time was faster in the competition group ($P = 0.006$). Differences in participation continued to increase over the duration of the

intervention, as measured by average response time and cumulative percent of questions attempted (each $P < 0.001$).

Conclusions: Team competition increases resident participation in an online course delivering QI content. Medical educators should consider game mechanics to optimize participation when designing learning experiences.

Key words: graduate medical education, randomized controlled trial, quality improvement, spaced education

Introduction

Physicians of the future will increasingly practice in a clinical environment that links patient safety, explicit measures of care quality and reimbursement to health outcomes [1–4]. Preparing resident physicians for independent practice in this new paradigm will require engagement in quality improvement (QI) and patient safety in the clinical learning environment during training [5]. However, a number of challenges impede the implementation of educational programs about healthcare quality, including competing clinical obligations, lack of perceived value and distribution of learners across multiple sites [6].

Given this context, it is critical to understand how to enhance resident engagement in QI education. One potential method to increase learner participation is through the use of team-based competition. Game mechanics, such as team-based competition, status indicators and social collaboration can drive behavior change [7–10]. However, to our knowledge they have never been evaluated rigorously in the context of enhancing resident participation in QI education. We hypothesized that a competitive environment would increase participation in the educational program. To explore this issue, we created a curriculum about QI and patient safety delivered via an evidence-based, mobile learning platform [11–13] that specifically addresses barriers to teaching QI. The mobile device based platform provides an asynchronous, distributed learning experience that integrates easily into resident workflow by creating learning interactions lasting minutes, rather than requiring an hour for traditional lecture formats. To test our hypothesis, we conducted a randomized trial to evaluate the role of team-based competitive game to increase residents' QI participation.

Methods and materials

Design overview and participants

The goal of this randomized controlled trial was to test whether a team-based competitive environment would increase participation relative to an environment with only individual feedback. In order to focus on the effect of competition, we sought an educational approach with demonstrated efficacy. The technique of 'spaced education' (SE) durably increases knowledge uptake and retention [11, 12, 14] via effects grounded in core psychological learning principles, and in several randomized trials has been demonstrated to be content-neutral, produce durable knowledge uptake and foster changes in learner behavior [12–16].

Between November 2012 and January 2013, program directors from nine residency programs (anesthesia, emergency medicine, family medicine, internal medicine, ophthalmology, orthopedics, pediatrics, psychiatry and surgery) at the David Geffen School of Medicine, University of California, Los Angeles opted to participate in the online course. All residents from participating programs were enrolled as part of an institutional QI education initiative. The format and educational content of the program were identical for all participating residents, with the sole exception of whether the educational environment included competition elements (Table 1). The institutional review board of UCLA determined that the educational course was a QI activity, and approved the secondary analysis and dissemination of de-identified participant data.

Development of content

The educational content for the course was structured in a question–explanation format to take advantage of the testing effect (e.g. testing improves recall) [17, 18]. Twenty key 'take-home messages' were identified from review of the QI literature and an existing QI lecture series for residents at UCLA, and then content-validated by a panel of 28 nationally recognized quality/safety experts. Forty separate question–explanation items were developed (2 per 'take-home message') which focused on core healthcare quality and safety issues. We pilot tested 40 potential questions among a group of 34 residents and fellows, and subsequently used 20 of these questions. We constructed detailed explanations to provide a take-home message, explain the answers and provide hyperlinks to learning resources.

Content delivery

The program uses an automated system (Qstream, Inc., Burlington, MA, USA; www.qstream.com) that emailed two questions twice a week to participants. Each participant in both groups received an email containing the same two questions simultaneously. Each email presented the scenario and question on healthcare quality issues. Upon clicking a hyperlink, a Web-page opened that allowed participants to submit an answer to the multiple-choice question. The answer was downloaded to a central server, and participants were immediately presented with a Web-page displaying the correct answer and a detailed explanation of the question content. The adaptive system repeated questions in 8 days if answered incorrectly and 16 days if answered correctly. The spacing intervals between repetitions were established based on research findings to optimize long-term retention of learning [19]. If a question was answered correctly twice consecutively, it was retired and no longer repeated (progression dynamic). The goal of the program was to retire all 20 questions, although this was challenging given the 10-week limited duration of the study.

Randomization and interventions

Residents were randomized with a computer generated sequence into two groups (Fig. 1), designated the competition group and the control group. In the competition group, participants were assigned to a team of fellow residents in the same specialty, a rock-band alias and feedback on relative standing via team leaderboards. Control group residents only received feedback regarding individual progress (questions attempted and retired). Otherwise, all participants received an identical educational experience. Program directors were blinded to group assignment.

Table 1 Educational program elements, by group

	Team competition group	Control group
Interventions	• Spaced delivery of interactive healthcare quality questions via email • Adaptive reinforcement of content based on performance *Plus* • Team assignment • Rock-band alias (e.g. Peds Talking Heads) • Team leaderboards • Individual leaderboards with aliases	• Spaced delivery of interactive healthcare quality questions via email • Adaptive reinforcement of content based on performance
Prizes	$10 for individual completion $30 for all members of top team	$10 for individual completion $30 for randomly-selected individuals

Both groups received an identical education program with adaptive reinforcement based on performance. In the team competition group, participants received additional interventions (e.g. team assignment) to promote a sense of competition.
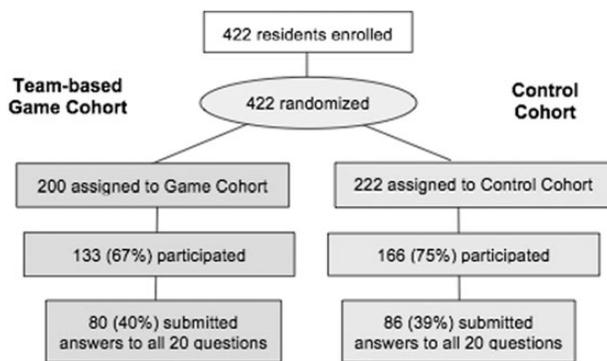
Figure 1 Modified CONSORT flow chart of the randomized controlled trial.

All residents in both groups began the program simultaneously in November 2012.

Teams were created to tap into the tribal allegiance within specialties to provide social context and motivation to engage in the program. There was no structured peer-to-peer learning as part of this intervention. We did not monitor or promote discussion on the topic material between residents within teams. That said, we also did not ask residents to avoid discussing the topic material with teammates. While such discussion might raise concerns of 'cheating' among participants, no such concerns were reported and we felt that the educational value of group discussion on these topics outweighed these concerns.

Rules of the game

In our program, learners periodically receive emails containing a link to a clinical scenario and multiple-choice questions. When the learner submits a response, she is immediately provided the correct answer and an explanation. The program repeats questions over intervals of time ranging from 1 to 6 weeks to reinforce long-term retention of learning.

Residents in the competition group were assigned to a team of fellow residents in the same specialty, ranging in size from 7 to 25 (Table 1). Points were awarded based on residents' performance on the questions. In each email and after each question, leader boards of individual performance (as reflected in running point totals) were posted online for other competition-group residents to view. To introduce humor and provide a safe environment for residents to answer

unfamiliar questions, the residents' names on the leader boards were replaced with the names of rock bands for de-identification (i.e. 'Peds Talking Heads'). Each week, aggregated team leader boards displaying team standings were distributed via email to all competition group residents. In the competition group, each resident who answered all 20 questions at least once received a $10 gift card. Each of the members of the single team with the highest average score at the end of the game received a $30 gift card. Residents in the control group received the identical educational content in an identically structured course, but without the team assignment, leader boards, rock-band alias or $30 prize for team-based performance (Table 1). Similar to the competition group, each individual resident in the control group who answered all 20 questions at least once received a $10 gift card, and among these residents, 12 were then randomly selected to receive a $30 gift card. Thus, the overall monetary value of the prizes offered to both groups was similar.

Outcome measures

We sought to test the hypothesis that elements of team competition would result in greater learner participation as compared with controls not exposed to competition elements. Therefore, our primary outcome was the percentage of questions that participating residents answered at least once. Secondary measures of engagement included (i) response time to answer a question for the first time; (ii) the proportion of participating residents who attempted all 20 questions at least once and (iii) the percentage of questions that participating residents retired over the game's 10-week duration (reflecting residents' ability to master the content by answering the questions correctly twice-in-a-row separated by a 16-day interval). Baseline scores measured residents' pre-course knowledge of content and were calculated as the percentage of questions answered correctly upon initial presentation among those residents who submitted an answer to all 20 questions. All data were automatically collected by the learning platform.

Statistical analysis

Assuming an average 75% of questions attempted at least once, 80% power and a two-sided α of 0.05, we calculated a target sample size of 193 participants per group. We planned two analyses: intention-to-treat (ITT; all residents randomized) and per-protocol (all residents attempting at least one question). Conceptually, the per-protocol analysis reflects to a greater extent the competition effect; if learners never

start the educational program (ITT analysis), then they are never exposed to the competition environment (or any other game elements).

Neither the primary outcome (percentage of questions that participating residents answered at least once) nor average response time were normally distributed, and therefore we compared these measures between groups using the Wilcoxon rank sum test. In addition, we tested the hypothesis that these two measures changed differentially over time in the two groups using a repeated measures ANOVA regression framework. The proportion of participating residents who attempted all 20 questions at least once was assessed by χ^2 test. Baseline scores were assessed using the Wilcoxon rank sum test. Analysis was conducted using SAS 9.2 (Cary, NC, USA). All hypothesis testing was two-sided, with $\alpha = 0.05$.

Results

Participant demographics
Demographic characteristics were balanced among randomized residents (Table 2). Initial response rates among enrolled residents (as defined by submitting an answer to at least one question) were similar between groups (control group: 166/222, 75%; competition group: 133/200, 67%, $P = 0.0685$).

Participation measures
In the ITT analysis, participation in the competition group improved over time. For example, the average first response time per question decreased among competition residents, but increased among the control group ($P < 0.001$ for interaction). Similarly, learners in the competition arm increased participation more rapidly than in the control arm ($P = 0.006$ for interaction). At the conclusion of the trial, the cumulative percentage attempted at least once and the median response time favored the competition arm, but were not statistically significant due to the high variance from those residents who did not begin the course.

Table 2 Baseline demographic characteristics of randomized residents

Resident characteristics	Game group	Control group
Participants in trial	200	222
Gender		
Male	104 (52%)	101 (45%)
Female	96 (48%)	121 (55%)
Post-graduate year		
PGY-1	55 (28%)	72 (32%)
PGY-2	68 (34%)	76 (34%)
PGY-3	63 (32%)	56 (25%)
PGY-4	14 (7%)	18 (8%)
Specialty		
Anesthesia	40 (20%)	25 (11%)
Emergency medicine	22 (11%)	29 (13%)
Family medicine	14 (7%)	21 (9%)
Internal medicine	51 (26%)	50 (23%)
Ophthalmology	12 (6%)	12 (5%)
Orthopedics	10 (5%)	19 (9%)
Pediatrics	36 (18%)	51 (23%)
Psychiatry	8 (4%)	7 (3%)
General surgery	7 (4%)	8 (4%)
Specialty type		
Medical	131 (66%)	158 (71%)
Surgical	69 (35%)	64 (29%)

Percentages may not total 100% due to rounding.

In the per-protocol analysis, competition residents attempted more questions at least once than control residents (competition, 79% [SD ± 32] versus control, 68% [SD ± 37], average difference 10.6% [95% CI 2.5%–18.6%], $P = 0.0331$). Residents in the competition group also retired more questions than control residents, although this result was not statistically significant (34% [SD ± 35] versus 27% [SD ± 33], respectively, $P = 0.056$). Residents in the competition group responded substantially faster to questions than control group residents (competition median 11.7 [IQR 2.5–35] days versus control group, median 26.6 [IQR 5.4–54] days, $P = 0.006$).

In the per-protocol analysis, participation improved in the competition group over time. Among residents who answered all 20 questions, the average first response time per question decreased among competition residents, but increased among control residents (Fig. 2, $P < 0.0001$ for interaction). The same effect was noted among all participating residents ($P < 0.0001$ for interaction). Similarly, the cumulative percentage of questions attempted by residents in the competition group increased more rapidly than the control group (Fig. 3, $P < 0.0001$ for interaction).

Knowledge measures
Among residents who submitted at least 1 answer to all 20 questions, baseline knowledge was similar between 2 groups. In the control group, the average correct first response rate was 41% (SD 12), as compared with 45% (SD 11) in competition residents ($P = 0.127$). There were no significant differences in baseline scores by specialty, gender or specialty type (medical versus surgical). Additionally, there were no significant differences in knowledge of healthcare quality with increasing residency experience.

Discussion

In this novel randomized controlled trial based in an online educational game, team-based competition increased resident physician engagement. Across several measures, residents exposed to a team-based competitive environment participated to a greater extent. Moreover, we observed a dose–response effect, in that participation measures improved more with increasing duration of exposure to the competitive environment. That is, the longer the participants were exposed to the
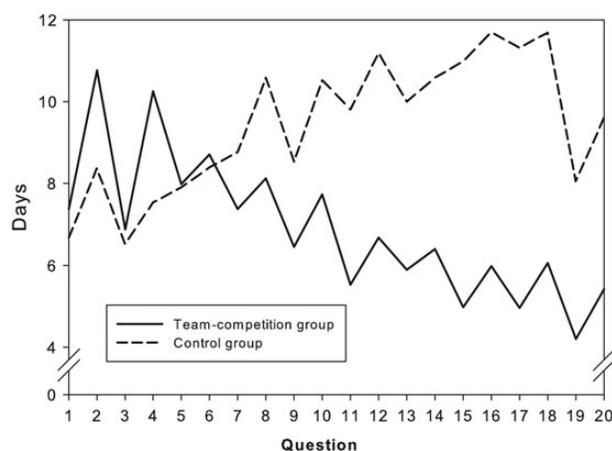

Figure 2 The average time of response (days) to answer a question for the first time. Questions are listed in chronological order across the *x* axis (denotes progress through educational course, per protocol analysis; similar results for intention-to-treat).
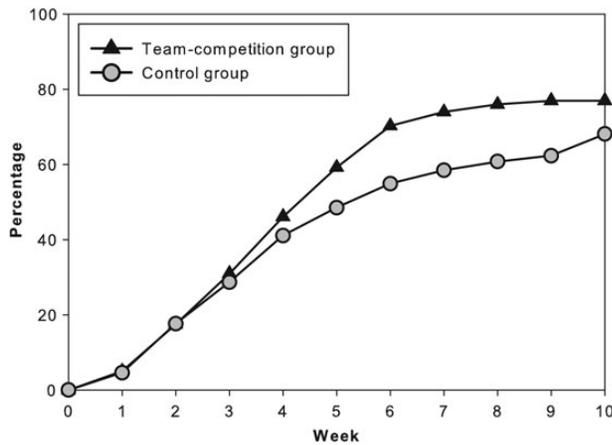
Figure 3 The average cumulative percentage of questions attempted at least once, by group. Weeks across x axis denote progress of educational course (per protocol analysis; similar results for intention-to-treat).

competitive environment, the greater the difference from the control group (Figs 2 and 3). These results suggest an important role for the social context of education as a lever to increase learner engagement.

Game mechanics, including team-based competition, can be powerfully motivating. Leader boards create a social competition dynamic, which may affect reward-processing neural systems [20]. These neural systems can have both positive and negative effects on engagement and motivation; negative effects can be mitigated via anonymity [21]. To achieve this end, we assigned humorous code names based on participant specialty and popular music groups. Leader boards provide a sense of status, which motivates participation [7, 22]. Incorporating these game elements into the design of our QI course improved participation compared with the control group.

We opted for an intervention using an online platform because its features directly address existing barriers to QI education. Learning is asynchronous and the platform is compatible with mobile devices, permitting distributed interactions across time and location. Interactions require only 2–3 min, thereby integrating well into resident workflow. The content-neutral format is evidence-based and takes advantage of the psychological learning effects of spacing and testing [13]. The 'spacing effect' is the observation that information presented and repeated over spaced intervals exhibits greater uptake and durable retention than information presented at a single time-point [23–25]. The spacing effect appears to have a neurophysiological and molecular basis [26, 27]. The testing effect suggests that the process of testing alters the learning process such that new knowledge is better retained [13, 17, 28].

Randomized trials have demonstrated that SE can increase learning, boost long-term knowledge retention and durably improve clinical behaviors. Therefore, we applied this evidence-based technique to the problem of transmitting foundational QI knowledge to resident physicians as a first stage in a program to broadly engage residents in improving healthcare quality [29].

Our findings must be considered in the context of several limitations. Knowledge of QI methodology is necessary, but likely insufficient to drive high quality healthcare delivery—the ultimate aim of resident education. The goal for our deployment of an online QI course was to overcome barriers to dissemination of an existing lecture-based curriculum. An ideal intervention would provide evidence of physician behavior change relevant to patient-important outcomes. Randomized trials suggest that SE techniques can drive durable

behavior modification, including behaviors related to healthcare quality [13, 16]. Team-based competition is also effective in achieving other important behavioral outcomes. For example, team-based incentives and social influence can successfully enhance weight loss and smoking cessation interventions in patients [8–10]. These data suggest that SE incorporating game mechanics may be a feasible intervention to drive physician behavior related to healthcare quality. The percentage of residents who retired all 20 questions was lower than ideal, but this is not unexpected given the study's 10-week limited duration. Although many participants responded within minutes or hours of questions being posted, the average participant response time overall was relatively high (days); this longer-than-expected response time may have been fueled by a distaste that many residents have to what can often be a dry topic area. The fact that response times among competition group residents improved over the duration of the game in contrast to those among control residents, which actually worsened over the course of the game, provides further evidence as to the power of team-based game mechanics to drive engagement. Program directors (blinded to group assignment) encouraged participation in the education program to a varying extent, thus additional promotion efforts targeting residents could improve response time.

There are several 'lessons learned' from this trial that will inform our future implementations of this team-based competition. First, participation rates in different residency programs varied, potentially due to the challenges of delivering content in a clinical context accessible to a broad range of specialties. Thus, future programs may wish to target groups of similar specialties (e.g. surgical specialties). Secondly, leadership support at the individual program level, particularly in prioritizing QI education, was also important. Finally, informal participant feedback suggested that questions based on clinical scenarios were more engaging than those focusing on rote facts (e.g. number of hospital deaths annually from medical errors). These opportunities to improve notwithstanding, competition between teams clearly seems to improve participation, and is recommended for future programs using this platform.

Conclusion

Game mechanics that create a sense of team-based competition in a safe learning environment are an effective way to engage residents in an online program of SE. Mobile, asynchronous educational technologies, similar to those employed here, offer significant potential to overcome many of the barriers related to teaching QI methods. Future efforts should be directed towards designing and assessing educational programs that incorporate game mechanics, in order to improve the delivery of high quality care by residents and practicing physicians.

Supplementary material

Supplementary material is available at *International Journal for Quality in Health Care* online.

Conflict of interest

Harvard University submitted a patent application on the spaced education methodology; while B.P.K. is cited as the inventor on the patent application, Harvard University has full ownership of the intellectual property. B.P.K. is an equity owner and director of Qstream, Inc., an online platform launched by Harvard University to host spaced education outside of its firewalls. C.D.S. was a member of the Board of Directors of the Accreditation Council for Graduate Medical Education at the

time the study was planned and conducted. He received no compensation for this service other than reimbursement of travel expenses. None of the other authors have conflicts of interest to disclose.

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