TEACHING INNOVATIONS

Impact of readiness assurance process and faculty feedback on individual application exercises: a model for continuous assessment in physiology

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Nayak KR, Punja D, Suryavanshi C. Impact of readiness assurance process and faculty feedback on individual application exercises: a model for continuous assessment in physiology. Adv Physiol Educ 44: 509–515, 2020; doi:10.1152/advan.00065.2020.—This study is aimed at the implementation of a continuous assessment model in physiology for a large-enrollment classroom with 250 students. The readiness assurance process (RAP) and immediate feedback elements from team-based learning (TBL) methodology were adopted to test their ability to guide students to solve applications exercises individually. Three continuous assessments in physiology (CAPs) were conducted with the RAP to include individual (iRAT) and group readiness assurance tests (gRAT). Immediate feedback was provided with faculty-student discussion (FSD), and the individual application exercises (iAE) were designed to be answered individually. Each CAP was subjected to three types of experimental manipulation in subgroups created out of 250 students. The intervention began with iRAT for all three subgroups. The sequence of iRAT, gRAT, FSD, and iAE varied between subgroups within a CAP. In a cross-over study design, each subgroup of students was subjected to all three intervention types over three CAPs. The subgroup completing iAE after RAP and FSD showed higher scores than the subgroup with RAP alone. One hundred eight-two students (82.35% response rate; 101 women and 81 men) responded to the questionnaire. The majority of students (87.4%) felt that doing iRAT and gRAT at the beginning helped them to solve iAE better. Most of the students (86.8%) responded that they received useful feedback and clarification during the discussion with the teacher after the gRAT. In conclusion, the administration of iRAT first followed by gRAT and immediate feedback from faculty seem to be beneficial to prepare students to tackle individual application exercises.

active learning; application exercises; clinical reasoning; collaborative learning; faculty feedback; formative assessment

INTRODUCTION

The medical education in India is challenged by a skewed faculty-student ratio with fewer faculty and a large number of students. Various institutes manage up to a maximum of 250 annual enrollment per individual institute. Teaching-learning strategies have to enshrine principles of active learning (12) with scope for peer and collaborative learning (11, 32). The pedagogical framework has to provide means to reflect clinical context and teach clinical reasoning as early as from the first year of medical training. The students have to be equipped with problem-solving skills with the ability to apply core concepts learned in basic sciences to clinically relevant situations (9). For novel teaching-learning methodologies, the teacher has to become an instructional designer, creating an effective learning environment, identifying appropriate learning resources, facilitating collaboration with peers, and challenging students to a higher level of learning. The core activities in team-based learning (TBL) can deliver these educational principles and are suitable to practice in large-enrollment classrooms. The structured processes in a TBL provide students with opportunities to apply conceptual knowledge through individual work, teamwork, and immediate feedback (25).

The preclass preparation with reading material prepared by teachers enables students to come prepared individually (15), whereas the readiness assurance process (RAP), consisting of individual (iRAT) and group readiness assurance tests (gRAT), ensures that students have the essential knowledge to solve application exercises (22). The graded iRAT motivates students to read assigned reading material; gRAT engages students for learning in teams to earn good team scores (26). The application exercises finally challenge students to apply course concepts to solve case-based exercises (7). In addition to enhancing knowledge acquisition for the problem-solving skills (8, 14), the processes within TBL can facilitate the development of essential graduate competencies like teamwork and collaborative practice (4, 18).

We adopted RAP and the immediate feedback process from TBL as a methodology for three continuous assessments in physiology (CAPs), with an aim for guiding students to apply the conceptual knowledge through individual application exercises (iAE). We wanted to explore the influence of RAP and immediate feedback from faculty in the form of faculty-student discussion (FSD) on student performance. Hence, the application exercises were designed to be answered individually. This report is aimed at describing our implementation of CAP among a large-enrollment class of medical students and students’ evaluation of the process adopted for CAP. RAP was conducted with iRAT and gRAT. The iRAT/gRAT questions were discussed during FSD, and iAE had to be solved individually by students.

Objectives. With an experimental approach, our study explored how much would RAP and FSD contribute to the acquisition of conceptual learning by an individual student. In addition, what is the role of individual preparation as measured by iRAT? Does learning in teams during gRAT prepare stu-
dents to solve iAE? Furthermore, what is the role of the teacher to facilitate learning?

To achieve this, the large class of 250 students was divided into three subgroups. iRAT was administered first to all three subgroups. The sequence of administration of gRAT, iAE, and FSD were different between the three subgroups. We hypothesized that students administered with iRAT and gRAT would perform better in iAE compared with students with iRAT only. Furthermore, students undergoing RAP and FSD would perform higher in iAE compared with RAP only.

MATERIALS AND METHODS

Setting. The presented data are from the academic year 2018/2019. Out of the 250 students (129 men, 121 women) of the first professional year from Bachelor of Medicine and Bachelor of Surgery program at Kasturba Medical College, Manipal, aged 18–21 yr, 221 students participated in this study. In the first professional year, students learn human anatomy, physiology, biochemistry, and community medicine. The physiology course spans 12 mo, and three continuous assessments in physiology (CAPs) were conducted in three different systems in physiology. The other teaching-learning methods include didactic lectures, small-group tutorials, skills training, and laboratory exercises.

Study preparations. The students did not have prior experience with readiness assurance process (RAP), and this was their first exposure to RAP. At the beginning of the course, the procedure and grading system of RAP was explained to students. The principal investigator formed the teams randomly to prevent the students from organizing into preexisting groups based on familiarity. Each group was a mix of male and female genders. The groups remained stable for the entire year.

Preparation of RAP and iAE questions. Multiple-choice questions (MCQs) with case-based vignettes, testing the approach to clinical reasoning and application of fundamentals in physiology, were constructed for the central nervous system, renal physiology, and endocrinology for RAP and individual application exercises (iAE). About 25–30 questions were administered during RAP. The RAP questions were designed to test higher levels of learning that would require elaborate thinking from students to answer the questions both individually and in teams. The challenging questions in RAP were planned to promote deep discussion during group readiness assurance tests (gRAT), which might not have otherwise occurred if the questions were framed at the level of recall. The iAE questions (15 questions for each session) were prepared to be more complex than RAP questions. For the same learning outcomes, faculty had to construct questions to suit challenging RAP exercises and even more difficult iAE questions. The RAP and iAE questions were subjected to item analysis. Upon item analysis, we found that the discriminatory and difficulty indexes were higher in iAE compared with the RAP, although it did not reach statistical significance. The reliability coefficient (KR 20) of these tests ranged from 0.5 to 0.75. A sample of RAP and iAE questions from the first CAP is outlined in Fig. 1.

Structure of CAP. The student experience of a single CAP consisted of four key phases, namely pre-class preparation, RAP, faculty-student discussion (FSD), and iAE. Each CAP was announced 10–15 days in advance. The CAP was placed after lectures and tutorial and laboratory exercises were covered in the prescribed portions. The learning resources for assigned portions of CAP were made available from the institutional learning management system as PowerPoint slides for the lectures and for viewing recorded lectures. The students were instructed to read the two recommended graduate-level textbooks Ganong’s Review of Medical Physiology and Guyton and Hall Textbook of Medical Physiology (South Asian Edition). RAP was conducted in class with the administration of iRAT and gRAT. In iRAT, students answered the MCQs individually. During gRAT, the identical questions as given in iRAT were solved by the preassigned teams. During RAP, the students were not allowed to use resources, and there was no access to internet facility. The iRAT/gRAT questions were discussed between the faculty and students (FSD). The iAE questions had to be answered individually by students, and these questions were not discussed with them.

Six classrooms were utilized for each CAP, accommodating 40–42 students per classroom. An individual instructor from the Department of Physiology supervised every classroom. For iRAT, students were seated separately to complete answering 25 MCQs in 35–40 min. The students were organized into five- to six-member teams for gRAT. Seven or eight such teams were formed in individual classrooms for conducting gRAT. gRAT was completed by teams in 20–30 min. The discussion of iRAT/gRAT questions between faculty and students occurred over 0.5-h duration. Another 20 min were allotted for solving iAE.

Faculty training and development. Two medical educators versed with team-based learning (TBL) pedagogy were identified from the Department of Medical Education at the university to conduct TBL training workshops to faculty in physiology. The selected medical educators had undergone training for TBL workshops under the International Union of Physiological Sciences initiative. The faculty workshops were mainly focused on facilitation skills, and completing this training was essential before facilitating sessions to students. In a phased manner, RAP and immediate feedback by faculty were first introduced into the curriculum, and these sessions were observed, allowing feedback to be provided to faculty to further improve facilitation skills and efficiently manage time (24). Application exercises in the form of iAE were later added to the subsequent batches, and the faculty were oriented to the process of CAP.

The faculty as subject experts curated content for pre-class readings. They developed and validated questions for RAP and iAE. The same faculty Functioned as facilitators during the delivery of CAP. Before the commencement of CAP, a separate senior lead faculty from the Physiology Department reviewed the learning resources and questions to check for the number of learning outcomes, alignment of learning objectives to pre-class readings, linking of learning objectives to RAT and iAE, and complexity of iAE.

Ethics statement. On approval of the project by the Kasturba Medical College and Kasturba Hospital, Manipal Institutional ethics committee clearance (IEC/370/2019), written consent was obtained from the students. Any identifiable information, such as names and unique student registration numbers, was removed and replaced by numeric codes before data analysis.

Study design. Each CAP was subjected to three types of experimental manipulation in subgroups created out of 250 students. The intervention began with iRAT for all three subgroups. In the first CAP, the sequence of events was iRAT-gRAT-FSD-iAE for subgroup A. The order of events for subgroup B was iRAT-iAE-gRAT-FSD. iRAT-gRAT-iAE-FSD was the sequence of events for subgroup C. In a cross-over study design, each subgroup of students was subjected to all three intervention types over three CAPs. Overall, every component was covered for the subgroups in three CAPs. The summary of the study design is illustrated in Fig. 2.

Incentive structure. The equal-weighted average of iRAT and gRAT scores was included in the internal assessment. The scores of iAE were not included in the internal assessment, since certain groups were benefitted by the intervention. RAP accounted for 25–30% of the overall course grades sizing up for the internal assessment. The remaining 70–75% of the grades were determined by three periodic assessments conducted at the end of every 12-wk teaching period. These periodic assessments consisted of MCQs, short- and long-answer questions, objective structured practical examination, and viva voce.
A survey using a series of five-point Likert scale questions was administered to gather feedback from the students at the end of the academic year. The questionnaire consisted of 19 items enquiring about the process of CAP.

**Statistical analysis.** One-way ANOVA was used to compare gRAT and iAE scores between subgroups within a CAP. Statistically significant main effects were further assessed with post hoc Bonferroni tests and statistically significant interactions with simple effects. iRAT and gRAT scores in a CAP were compared using the Wilcoxon signed-rank test. All tests were conducted with an experiment-wise α-level at 0.05.

**RESULTS**

Out of 250 students, 221, 218, and 181 students participated in first, second, and third CAP, respectively. The schedule of the third CAP happened to coincide with the University’s...
Fig. 2. Summary of the study design. CAP, continuous assessment in physiology; FSD, faculty-student discussion; iRAT and gRAT, individual and group readiness assurance test, respectively; iAE, individual application exercise.

annual inter-institutional fest, hence reducing the number of students attending the third CAP.

Scores from three CAPs. The results of this study are summarized below. iRAT, gRAT, and iAE scores are expressed as means ± SD.

The subgroup completing iAE after RAP and FSD showed higher scores than the subgroup with RAP alone. This was true for the second CAP. Subgroups with the administration of iAE before gRAT did not perform significantly better in iAE than the subgroups receiving iAE after gRAT. This was observed in the second and third CAPs (Table 1).

Student feedback on CAP. Overall, 182 students (82.35 response rate; 101 women and 81 men) responded to the questionnaire. The responses to each statement are shown in Table 2. The majority of students (87.4%) felt that doing iRAT and gRAT at the beginning helped them to solve iAE better. The majority of students (86.8%) responded that they received mistakes and learn more concepts. The majority of students (86.2%) agreed (87.4% and 88.4%) that different points of view were respected by team members, and the team elicited multiple points of view before deciding on a final answer.

Although students (62.7%) responded that their team members did the readings before the session, a few students (30.2%) were inconclusive about their team members doing readings before the session. The majority of students (86.2%) agreed that completion of the prescribed out-of-class preparation based on lecture, tutorial, and e-learning resources assisted their learning.

Students (82.9% and 61%) felt that the number of group members (five to six) enhanced their experience of peer learning and would prefer to have the same team members for all the CAPs conducted during the first year.

The majority of students (86.2% and 87.3%) thought that problem-solving using iAE allowed them to develop clinical reasoning skills, and clinical scenarios in MCQs developed the way they approached clinically oriented MCQs.

DISCUSSION

This study describes a continuous assessment model in physiology that was implemented to a large-enrollment class of first-year medical students. The readiness assurance process (RAP) and immediate feedback elements from team-based learning (TBL) were adopted to test their ability to guide students to solve application exercises individually. The single experience in continuous assessments in physiology (CAP)

Table 1. iRAT, gRAT, and iAE scores in all three CAPs

| CAP (n) | Subgroup (n) | Intervention Types | iRAT Score | gRAT Score | iAE Score |
|--------|--------------|-------------------|------------|------------|------------|
| 1 (221) | A (76)       | iRAT → gRAT → FSD → iAE | 16.76 (5.36) | 26.45 (1.71) | 7.47 (2.99) |
|        | B (79)       | iRAT → iAE → gRAT → FSD | 18.38 (4.22) | 25.87 (2.40) | 8.49 (2.91) |
|        | C (66)       | iRAT → gRAT → iAE → FSD | 16.77 (4.71) | 25.32 (2.38) | 7.62 (2.99) |
|        | ANOVA        |                   | P = 0.058   | P = 0.010*  | P = 0.072  |
|        |              | Bonferroni tests  | A > C, P = 0.007 |             |            |
| 2 (218) | A (63)       | iRAT → iAE → gRAT → FSD | 16.93 (3.85) | 22.78 (3.30) | 8.49 (2.50) |
|        | B (78)       | iRAT → gRAT → iAE → FSD | 15.82 (5.28) | 26.40 (2.30) | 7.54 (2.71) |
|        | C (77)       | iRAT → gRAT → FSD → iAE | 17.41 (4.40) | 25.12 (2.94) | 9.00 (2.54) |
|        | ANOVA        |                   | P = 0.089   | P < 0.001   | P = 0.002  |
|        |              | Bonferroni tests  | B > A*, P < 0.001 | C > A*, P < 0.001 | B > C*, P < 0.002 |
| 3 (181) | A (67)       | iRAT → gRAT → iAE → FSD | 16.45 (3.66) | 22.60 (3.04) | 6.81 (2.11) |
|        | B (51)       | iRAT → gRAT → FSD → iAE | 15.73 (3.02) | 20.57 (3.57) | 5.78 (2.41) |
|        | C (63)       | iRAT → iAE → gRAT → FSD | 14.05 (4.12) | 20.48 (3.47) | 6.33 (2.44) |
|        | ANOVA        |                   | P = 0.001*  | P < 0.001*  | P = 0.062  |
|        |              | Bonferroni tests  | B > C, *P = 0.049 | A > B*, P = 0.004 | A > C*, P = 0.001 |

Values are means (SD); n, no. of students, are shown in parentheses for continuous assessment in physiology (CAPs) and subgroups. FSD, faculty-student discussion; gRAT, group readiness assurance test; iRAT, individual readiness assurance test; iAE, individual application exercises. gRAT >> iRAT in each subgroup across all CAPs. *P < 0.001.
start with assigned pre-class readings, and the in-class activities exposed students to readiness assurance process (RAP), faculty-student discussion (FSD), and individual application exercises (iAE). Furthermore, with an experimental approach, we explored to what extent the structured activities within CAP would interact and contribute toward the acquisition of conceptual knowledge for clinical application. A recent study reported on novel TBL-based approaches practiced in large classroom settings to enhance student understanding for tougher course concepts, wherein the team-based review was designed based on TBL methodology, with only group readiness assurance tests (gRATs) administered without individual readiness assurance tests (iRATs) to encourage student debate and discussions for knowledge acquisition (1).

From our results, it is evident that CAP with immediate feedback from faculty enables students to solve iAE better (Table 1). iAE required students to think critically and apply concepts to clinically relevant situations. The facilitator ensures the effective engagement of members within a team, facilitates interteam dynamics and elicits answers from the whole group, and challenges learners’ assumptions before revealing the right answers (13). The discussion between the faculty and groups assist learners in articulating difficult concepts and clarifying or resolving misconceptions. RAP provides a means for faculty to assess gaps in knowledge and understanding to address specific needs (31). Students learn best with immediate feedback, and faculty serve as a...
vehicle for timely feedback (3, 17). Hence, the students are better prepared to answer iAE after RAP, coupled with immediate feedback from faculty. The student evaluation reiterates this finding, since the majority of students (86.8%) responded that they received useful feedback and clarification during the discussion with the teacher after the gRAT. The systematic guided discovery approach to learning facilitated by subject specialists is a high point of a methodology based on TBL, and this was perceived as an enriching educational experience by students in an earlier TBL-based study (24a). The instructional strategy provided by peer discussions and feedback from faculty exposes learners to alternate views, reforms interpretations to develop new mental constructs of understanding, and conforms to the constructivist theory of learning (18, 19).

To function effectively in a group, the members have to demonstrate individual responsibility and accountability by committing to pre-class readings (22, 29). Only 62.7% of students from our study reported that “my team members did read the readings before the session.” Data from a recent study reports that incomplete preparation by the student cohort can interfere with the efficacy of TBL, ultimately reflecting as poor performance on the final examination (5).

The group members have to listen to each other, encouraging diverse viewpoints before making decisions for the answer choices. The team spirit and camaraderie were expressed in the student feedback when the majority of students (88.4%) responded: “my team actively elicited multiple points of view before deciding on a final answer.” The majority of participants found the team size of five to six students satisfactory for peer learning and did not suggest that the team size be increased. Previous literature suggests that effective student teams should be large enough to generate diverse perspectives, yet small enough to promote meaningful interaction and foster team dynamics to develop into high functioning teams (23).

A highly structured instructional and assessment strategy like CAP requires superior planning and organizational and teaching skills from instructors. The faculty functions as a subject expert and a facilitator (28). As subject experts, faculty have to develop and curate learning resources for pre-class preparation. There were 86.2% of students who opined that “completion of the prescribed out of class preparation based on lecture, tutorial and e-learning resources assisted my learning.” Constructing test material with challenging application exercises with relevant clinical correlates is essential for content experts (4). Learning basic sciences in a clinical context enables integrating the theoretical knowledge with the clinical application (2). The design of application exercises in our study was found useful, since 86.2% of students mentioned that “problem-solving using iAE allowed me to develop my clinical reasoning skills.”

In our study, iAE was not included in the incentive structure; only iRAT and gRAT scores were incorporated into individual student’s overall course grades. A previous study said that ungraded application exercises were perceived as less stressful by students, leading to improved learning environments without sacrificing outcomes in knowledge acquisition (6). However, when application exercises were graded in TBLs, this component was assigned the highest percentage of scores that can be obtained by an individual student. Although we undertook iRAT and gRAT as an equal-weighted average for grading student performance from a single CAP exercise, there are reports in which iRAT is given larger weightage of up to 70% in TBL-based curriculum (24a). The higher weight for iRAT is practiced to encourage greater individual preparation.

Testing using RAP is not just a means for grading: it also serves as a tool for teaching. Collaborative learning and assessment activities have validity as assessment for learning and thus RAP can aid as an instrument for formative assessment (16). RAP systematically makes students first self-discover shortcomings in their learning, and peer discussion uncovers the most challenging areas for groups to master. RAP makes students reflect on what they do not know, and this is also feedback for teachers to rely on during faculty-student interaction. Discussion is the time when faculty gets a peek into what kind of concepts are harbored by students, and teaching pearls can emerge, considering the correct and incorrect reasoning offered by students. In earlier studies, pedagogical methods promoting peer discussion or collaborative learning first, followed by interaction with instructors, have been shown to increase student performance in quizzes consisting of higher intellectual questions (27).

From our study, it is not clear if the elimination of group application exercises has restricted the complete development of team skills. Future studies can design experimental manipulation to factor in group application exercises. The structured CAP of this nature requires elaborate preparation from both students and faculty. The assessments from multiple courses and extracurricular activities compete for student time and attention. Protected time should be ensured in the academic schedule when structured CAPs are planned to allow students to undergo optimal preparation and actively participate in-class activities. The present study provides some useful information about the benefits of RAP and FSD for assisting students in solving iAE. It is, nevertheless, a study limited by variation of student numbers across three testing cycles, and further consideration of study designs have to include measures to ensure constant student cohorts.

Conclusions. The instructional methods designed have to engage students with study material and facilitate interaction among peers and between students and faculty with ample scope for formative assessment and feedback. A model like CAP blends the process of learning with testing and stages adequate opportunities for faculty to provide feedback. RAP with feedback from faculty favors the development of the knowledge state to equip students to solve clinical problems. The sequence of activities has to take into consideration the assessment of the initial knowledge of students and then gradually build on problem-solving skills. The administration of iRAT first followed by gRAT and immediate feedback from faculty seem to be beneficial to prepare students to tackle application-based exercises. The role of the faculty is central in developing learning resources and test material and acting as a facilitator to provide immediate feedback.

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DISCLOSURES

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