

INVESTIGATION OF ONLINE COMPUTER-BASED FORMATIVE ASSESSMENT (CBFA) AND TRADITIONAL CLOSED-BOOK PAPER-BASED ASSESSMENT IN PHARMACY UNDERGRADUATE TEACHING

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Introduction

The choice of assessment format is instrumental in shaping our students' learning behaviour and consequently, the learning outcome. It has been shown that high quality formative assessment has a positive effect on student learning both in general (Olson & McDonald, 2004) and specifically in pharmacy education (Andrew, 2000). Here at the Department of Pharmacy, the majority of formative assessments are administered as traditional closed-book paper-based examinations. While this in itself is not a problem, the inadvertently memory-intensive nature of our curriculum, coupled with a heavy academic semester schedule, can detract most students from enhancing their learning beyond the boundaries of their course materials while they prepare for course assessments. This learning gap is accentuated in application-based subjects, where concepts delivered in the classroom should enhance a deeper understanding and enable effective application of these concepts across real-life examples. Hence, the vast electronic information which is freely accessible to all becomes an untapped resource for supporting students' learning.

Therefore, to overcome these challenges, we considered the value of an "open-resource" assessment format, as opposed to the traditional closed-book assessment. By "open-resource", students have free access to all information (both print and online) during the entire session of the assessment. This is a step up from "open-book" assessment format, whereby online access becomes an additional platform for information and test administration. Some of the reported benefits associated with computer-based formative assessment (CBFA) include the opportunity to incorporate new media technologies into questions (video, animation and sound), achievement of the objectives, anonymous marking as well as addressing the needs of students with certain disabilities. Despite these benefits, the value of CBFA has not been widely investigated, especially with regards to pharmacy students in Asia. As learning experience and outcome are influenced significantly by cultural diversity and the degree of exposure of students to e-learning and e-assessment, it becomes important to investigate and establish the role of CBFA in the teaching of pharmacy students in Singapore, and to compare our data with the outcome observed by our European counterparts.

To explore this option objectively, we introduced CBFA in a fourth-year pharmacy elective module, PR4207 "Applied Pharmacokinetics and Toxicokinetics", and surveyed students' perception of the applicability of this mode of assessment. We compared the students' experiences against another traditional closed-book assessment conducted within the same module. Our goal was to determine if an online CBFA will modify students' learning habits towards a preference for self-directed learning. Our current findings can help to establish the role of online CBFA in the teaching of pharmacy students in Singapore and beyond.

Methods

Our sampling target comprised all sixteen final year pharmacy undergraduates that undertook the elective module PR4207 "Applied Pharmacokinetics and Toxicokinetics" in Academic Year 2009/2010. The students were briefed on the two modes of assessment at the beginning of the semester: the online CBFA and the closed-book paper-based assessment. We had the students fill out a questionnaire comprising four broad categories aimed towards eliciting their views on the attributes of online CBFA, the challenges of using it, their preference for online CBFA and finally, their attitudes towards this assessment mode compared to the closed-book paper-based assessment. For both assessments, students had to complete a two-hour test comprising both multiple-choice and free-response questions. In order to alleviate any disparity in terms of the nature and quality of the questions posed in both assessment modes, as well as the level of difficulty and the projected time spent, the questions were carefully reviewed by two faculty members to ensure their consistency.

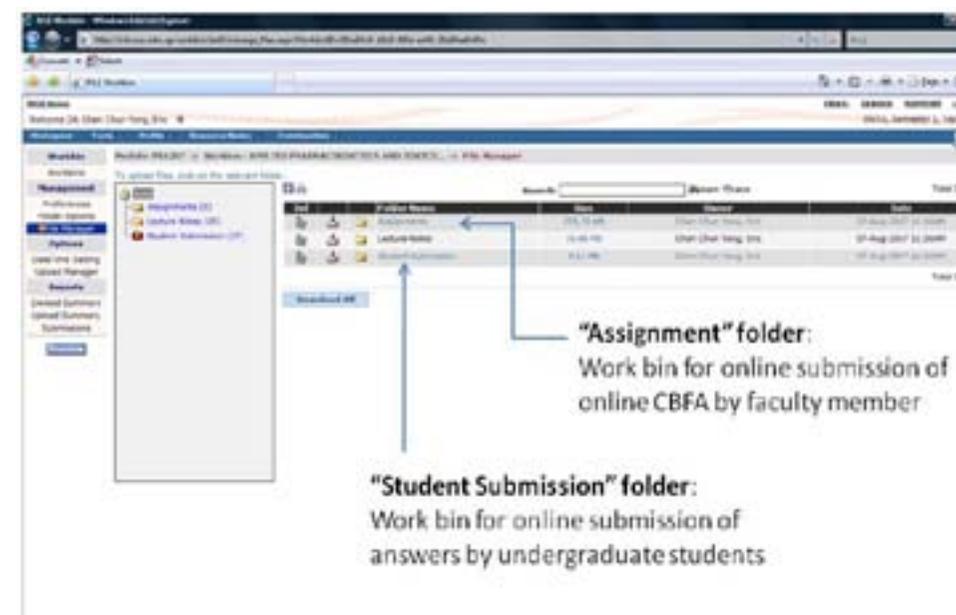


Figure 1. The IVLE and its associated work bins for online submission of questions and answers related to the online CBFA.

We also explored using the university's Integrated Virtual Learning Environment (IVLE) system to administer the online CBFA. Questions related to the online CBFA were proofread and transferred to the IVLE. The IVLE's login authentication system ensured students' identities were kept confidential, timed the release of the assessment questions and also timed the upload of the electronic answers (see Figure 1). No invigilation was provided for the online CBFA.

The closed-book paper-based assessment was performed using the traditional classroom-based invigilation approach. The assessment was formulated as a closed-book examination where the students had no access to information in the public domain or their lecture handouts. All sixteen students were subjected to both assessment modes in a longitudinal fashion during the semester (the online CBFA followed by the closed-book paper-based assessment).

The questionnaire was administered to the students one week after the closed-book paper-based assessment. They were asked to rate their levels of agreement with each statement in the questionnaire. Responses were anonymised and rated on a five-level scale with end-points ranging from "strongly agree", "agree", "neutral", "disagree" to "strongly disagree". Completed questionnaires were entered into Microsoft Excel spreadsheets where descriptive statistics were performed.

Results

All sixteen students participated in both assessments and submitted the questionnaires. The administration of online CBFA did not encounter any technical challenges. Examples of these assessment questions are illustrated in Figures 1A and 1B.

<p>Drug absorption profiling is becoming increasingly important during the early drug discovery phase. Multiple techniques exist in the pharmaceutical industry for the profiling and rank-ordering of oral drug absorption among drug candidates.</p> <p>P-glycoprotein (Pgp) has been demonstrated to affect the absorption of clinically important drugs via Pgp-mediated efflux activity. Several <i>in vitro</i> methods have been developed for the screening of Pgp substrates. Given the following conditions and a suitable cell model, design and describe clearly (with suitable diagrams) an <i>in vitro</i> method that can be utilised for the screening of Pgp substrates (4 marks). Suggest two potential limitations of your proposed experiment (2 marks).</p> <p>a. Calcein is hydrophilic and has limited cellular permeability. b. Calcein-AM is a highly membrane-permeable nonfluorescent acetoxyethyl ester of calcein, a hydrophilic and fluorescent compound. c. Calcein-AM is a Pgp substrate. d. Calcein-AM is rapidly converted to calcein by intracellular esterase.</p>	<p>Concept of key subject matter (P-glycoprotein) was explained in class</p> <p>Test of critical thinking skills as the content of the questions (calcein-based experiment) was not discussed during the lecture.</p>
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Figure 1A. Sample question from closed-book paper-based assessment.

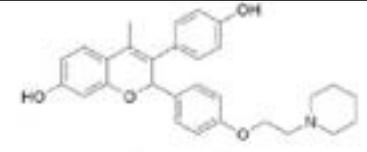
 <p>Compound X</p> <p>a) Propose one structural modification that you can introduce to reduce the potential toxicity of this compound (you do not need to consider the impact of the change on pharmacological effects). (2 marks) Why do you think your proposed structural change is less toxic? (2 marks)</p> <p>b) Provide another example of a real drug with a similar toxicophoric group and cite a paper that demonstrates experimental evidence indicating its toxicity. (3 marks)</p>	<p>Requires an understanding of the structural feature causing toxicity. Since this compound has not been described before, concepts will be applied to suggest rational replacement.</p> <p>This question allows the student to mine infinite online resources. Each student should generate a different response. The students will learn something new in the process of finding an answer.</p>
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Figure 1B: Sample question from the online CBFA.

Students' views on the attributes of online CBFA

The students' views on the attributes of online CBFA are presented in Table 1. Fourteen students (87.5%) recognised that the online assessment allowed them to identify their own strengths and gaps in the subject while twelve students (75.0%) felt that they had gained further insight to their approach to learning by completing the online CBFA. Thirteen students (81.3%) reported that they have learnt new knowledge by taking the online assessment, while fourteen students (87.5%) recognised some opportunities to modify their learning approach after attempting the online assessment. In addition, all sixteen students (100%) felt that the online CBFA triggered their self-learning beyond the classroom.

Table 1. Students' views on the attributes of online CBFA.

	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Online assessment allows me to identify my strengths and gaps in the subject	4 (25.0)	10 (62.5)	1 (6.3)	1 (6.3)	0 (0)
I have gained further insight to my approach of learning by completing the online assessment	5 (31.3)	7 (43.8)	3 (18.8)	1 (6.3)	0 (0)
I have learnt new knowledge on the subject by taking the online assessment	4 (25.0)	9 (56.3)	3 (18.8)	0 (0)	0 (0)
I can see some opportunities to modify my approach to learning by completing the online assessment	5 (31.3)	9 (56.3)	2 (12.5)	0 (0)	0 (0)
Online assessment triggers self-learning beyond classroom	7 (43.8)	9 (56.3)	0 (0)	0 (0)	0 (0)

Students' views on the challenges of online CBFA

The students' views on the challenges of online CBFA are illustrated in Table 2. Five students (31.3%) felt that performance in the online CBFA could be affected by the level of computer literacy while eight students (50%) did not recognise this as a challenge; the remaining three students (18.8%) remained neutral. Eight from the class (50%) felt that online assessment created a tendency for the student to discuss the answers with his/her peers; five students (31.3%) remained neutral about this, while the remaining three (18.8%) disagreed. In addition, the majority of the class (thirteen respondents, 81.3%) felt that the online CBFA demanded a greater understanding of the subject matter as compared to closed-book paper-based assessment.

Table 2. Students' views on the challenges of online CBFA.

	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
My level of computer literacy limited my performance in the online assessment	2 (12.5)	3 (18.8)	3 (18.8)	5 (31.3)	3 (18.8)
Online assessment creates a tendency for me to discuss answers with my peers	3 (18.8)	5 (31.3)	5 (31.3)	1 (6.3)	2 (12.5)
Online assessment demands greater understanding of the subject matter than paper assessment	7 (43.8)	6 (37.5)	2 (12.5)	1 (6.3)	0 (0)

Students' preference for future online CBFA

Table 3. Students' preference level for online CBFA.

	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
I would like to see the online assessment being implemented for more modules	3 (18.8)	8 (50.0)	3 (18.8)	2 (12.5)	0 (0)
I would prefer an online test rather than the conventional closed-book paper-based assessment	6 (37.5)	3 (18.8)	7 (43.8)	0 (0)	0 (0)

As shown in Table 3, eleven students (68.8%) would like to see the online CBFA implemented for other modules, while two students (12.5%) disagreed. Nine students (56.3%) preferred the online CBFA as compared to the conventional closed-book paper-based assessment while the remaining seven (43.8%) remained neutral towards this question.

Students' preference for conventional closed-book paper-based assessment

Table 4. Students' level of preference for conventional closed-book paper-based assessment^a.

	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
The combination of both closed-book paper-based and online assessment is an effective approach to assessing my learning and knowledge	4 (25.0)	10 (62.5)	1 (6.3)	0 (0)	0 (0)
I would prefer a conventional closed-book paper-based assessment rather than the online test	2 (12.5)	5 (31.3)	2 (12.5)	3 (18.8)	3 (18.8)

^a For each question, one student indicated that he/she was not sure what rating to provide. However, percentages were calculated based on a total sample size of 16 students.

As shown in Table 4, all except two students (87.5%) felt that the combination of both closed-book paper-based and online assessments is an effective approach to assess their learning and knowledge. Interestingly, seven students (43.8%) preferred a conventional closed-book paper-based assessment rather than the online CBFA, while six students (37.5%) did not support the statement. This particular question is similar to an earlier question which asked whether students would prefer an online CBFA assessment, and was intentionally designed as an internal control to validate the consistency of the students' responses. The exact complementary results we received (i.e. seven students preferring conventional closed-book paper-based assessment vs. nine students preferring online CBFA) confirms the authenticity of the responses.

Student performance in online CBFA versus closed-book paper-based assessment

The students' marks with regards to the online CBFA and closed-booked paper-based assessments are summarised in Figure 2. Except for three students (S3, S7 and S9), all the remaining thirteen students performed better in the online CBFA as compared to closed-book paper-based assessment. The mean scores for the online CBFA and paper-based assessment were 81.0 ± 11.1 and 64.2 ± 13.4 , respectively. It was clear

that two students (S5 and S15) performed significantly better in their online CBFA as compared to the closed-book paper-based assessments.

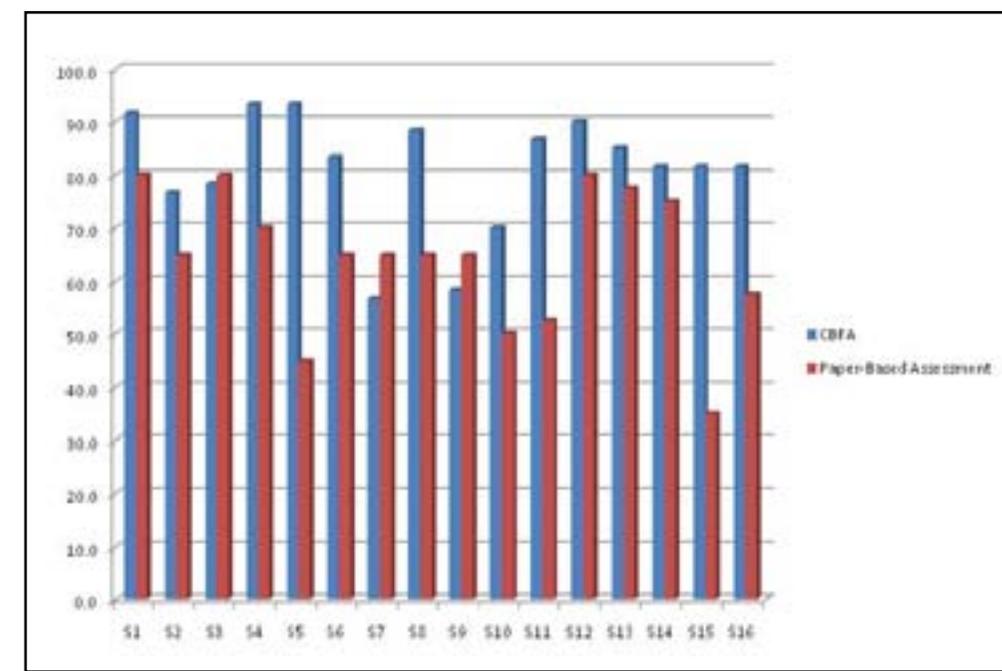


Figure 2. Performances of students with regards to online CBFA and closed-booked paper-based assessments.

Discussion

We conducted this teaching research within the context of a highly applied subject that expounds the factors that can alter the safety (toxicology) and efficacy (pharmacology) of medications. The concepts taught in this course serve to equip our students with the necessary mindset to critically evaluate drug safety matters to support both drug development and drug usage. The framework we established for our CBFA (i.e. open-resource format but time-limited assessment) in fact simulated an actual hospital pharmacist experience, whereby one has to provide a time-limited response to a drug-related query, given all the resources available at hand. Therefore, this assessment has the promise of preparing students for their professional practice.

In general, it was clear that the students recognised the benefits of the online CBFA in terms of improving their learning outcomes, with 87.5% of the students feeling they could better identify their strengths and gaps after taking the online CBFA. More interestingly, 81.3% of the students reported that they had learnt new knowledge by taking the online test. These results indicated that the online CBFA actually created an alternative platform for students to learn while they were being assessed. The unique "open resource" platform provided unrestricted

access to online resources during the test-taking process, thereby facilitating easy navigation as students explore the various resources in search for answers. In so doing, they garner new information that has enriched their understanding of the subject. Retrospectively, we found this to be an extremely powerful avenue for teaching because the student's attention span is maximised under an assessment condition and therefore translates into an opportunity for cognitive learning. That said, the success of this instrument for increasing learning will require carefully designed questions for it to be effectively exploited as an additional mechanism for teaching, rather than just a medium for factual regurgitation.

Another key observation from the study is the ability of an online CBFA to influence and modify learning behaviour. From our analysis, 75% of students reported that they gained further insight in their approach of learning while 87.5% noted opportunities in modifying their learning approach. With the briefing given to them at the start of the semester, students became aware of the assessment's open-resource format. This shaped their preparation by placing emphasis on understanding concepts rather than remembering facts. Efforts were also placed on encouraging students to explore online resources to familiarise themselves with these resources which cover relevant domain knowledge. In this process, they picked up new information which both enriched and challenged their understanding. This epitomises the essence of self-directed learning, which is an important preparatory skill for eventual professional practice as pharmacists. This exercise demonstrated that the online CBFA could perform the dual roles of assessment and education, and also trigger students' self-learning beyond the classroom.

In addition, the majority of students preferred the online CBFA and would like to see it implemented for other modules. This finding was consistent with that reported by the School of Pharmacy at the University of Manchester where 75% of their students expressed preference for online testing (Aojula, Barber, Cullen & Andrews, 2006). Yet, some of them were still relatively accustomed to conventional closed-book paper-based assessment and hence, there could be some inertia or resistance to change. This might explain why a large percentage of the students (85.7%) expressed preference for a combination of both closed-book paper-based and online assessments. This outcome suggests that intended implementation of similar online CBFA assessments should be done in a gradual and progressive manner, with follow-up surveys to qualitatively evaluate any change in receptivity to such assessments over time.

More students performed better in the online CBFA compared to paper-based assessment (Figure 2). As both assessments had been thoroughly cross-checked to ensure consistency in terms of their levels of difficulty, the observation suggested that students performed better in online CBFA compared to paper-based assessment. This might provide greater motivation for students to pursue self-directed learning. As the questionnaire was anonymised, it was not possible to track the responses of the two students whose performances in the two assessments were highly disparate.

However, this observation suggested a possibility that students who perform poorly in traditional memory-based assessment still possess the intellectual potential to perform well in an online-based assessment, where they have access to information in the public domain. While more research is needed to confirm this finding, the current data emphasised that students learn in a diversified manner and traditional paper-based assessment alone might not be the best tool to assess the learning outcomes.

The risk of cheating behaviour is deemed a necessary trade-off in achieving a flexible, non-supervised testing platform with unlimited access to information. Half of the class felt that the online CBFA created a tendency for students to discuss answers during the assessment. This outcome suggests that despite the merits of the open-resource format, the likely drawback due to a tendency to cheat has to be mitigated. One possible way to circumvent such behaviour is the use of computer clusters as examination rooms (Aojula, Barber, Cullen & Andrews, 2006). As most undergraduate students possess laptop computers and our university provides wireless internet surfing, they might also use their personal computers for the online CBFA in the examination venue.

In conclusion, the online CBFA is a useful tool to assess pharmacy undergraduate students in Singapore and has the potential to improve the learning outcomes of students. As NUS is a global university centred in Asia and our students are Asian-centric, our findings may be extended to the assessment of pharmacy students in other countries in Asia as well as for postgraduate pharmacy education.

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