

An online formative assessment tool to prepare students for summative assessment in physiology

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Background. The didactic approach to teaching physiology in our university has traditionally included the delivery of lectures to large groups, illustrating concepts and referencing recommended textbooks. Importantly, at undergraduate level, our assessments demand a level of application of physiological mechanisms to recognised pathophysiological conditions.

Objective. To bridge the gap between lectured material and the application of physiological concepts to pathophysiological conditions, we developed a technological tool approach that augments traditional teaching.

Methods. Our e-learning initiative, eQuip, is a custom-built e-learning platform specifically created to align question types included in the program to be similar to those used in current assessments. We describe our formative e-learning system and present preliminary results after the first year of introduction, reporting on the performances and perceptions of 2nd-year physiology students.

Results. Students who made use of eQuip for at least three of the teaching blocks achieved significantly better results than those who did not use the program ($p=0.0032$). Questionnaire feedback was positive with regard to the administration processes and usefulness of eQuip. Students reported particularly liking the ease of access to information; however, <60% of them felt that eQuip motivated them to learn.

Conclusion. These results are consistent with the literature, which shows that students who made use of an online formative assessment tool performed better in summative assessment tasks. Despite the improved performance of students, the questionnaire results showed that student motives for using online learning tools indicated that they lack self-directed learning skills and seek easy access to information.

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The traditional approach to teaching physiology at our university has been the delivery of a didactic lecture by an expert standing in front of the class. The lecture format usually involves the use of PowerPoint slides or chalk and a blackboard to illustrate concepts. After the lecture, students are referred to a recommended non-South African textbook.^[1] Frequently, especially in large medical student classes, the lecturer may be unavailable on a one-to-one basis for follow-up tuition. Therefore, students may find themselves in a situation where misconceptions or poorly received concepts are not easily addressed and corrected. These students may subsequently ignore or discard the information and consequently perform poorly in assessments. They could therefore overlook the relevance of the knowledge, which in the context of medical disciplines, may have an effect on their careers and ability to treat their patients. Moreover, diligent students who seek to further investigate a concept, frequently do not know where to find the relevant information in their textbook, the library or even on the internet.

A number of different emerging factors have made the challenges of effective teaching of healthcare professionals even more difficult in the local South African (SA) context. These include a changing school education system where disparate pedagogical approaches have been implemented over the last decade;^[2] a changing patient population, with the emergence of previously neglected or unknown diseases;^[3] and a lack of available resources, making clinical insight even more important as the primary tool available to healthcare workers. Consequently, long-established didactic approaches to the teaching of physiology may no longer fully meet the needs of current students or fulfil the demands for effective training of healthcare professionals. The promotion of active and self-directed learning,

which may be defined as the process in which students identify their learning niches and strengths and take the initiative to fulfil their learning requirements, may be achieved through an e-learning system^[1] that may prove to be a useful aid in supplementing the learning of students. A review article by Michael,^[4] focusing on physiological education, highlights the evidence that active learning approaches to teaching are more effective than passive methods. The evidence suggests that active learning promotes meaningful learning and performance is improved if these methods are employed. Online learning tools, which promote active learning by students, provide a supplemental resource through which students may engage the use of assessment with feedback, which potentially allows for tutoring that may not otherwise have been available.

There is evidence to suggest that e-learning tools are an effective method of providing additional teaching aids to students and also improve outcomes on summative test assessments.^[5] Formative assessment provides immediate feedback to students and promotes student learning, whereas summative assessment is an evaluation of student learning.^[6] e-learning systems are largely formative tools employed to assist students in summative assessment tasks.^[5] According to Velan *et al.*,^[7] the advantages of online formative assessments include 'immediacy of feedback, flexibility in time and place of undertaking the assessment; feedback can provide links to learning resources, thereby providing motivation to study, opportunity for repetition, and interactivity'.^[7]

Therefore, in our school, we have decided to embrace the technological approach to assist in meeting the needs of current learners. The use of computerised learning methods not only appears to lend themselves to the tech-savvy nature of the new generation of learners, but also allows students

to learn physiological concepts at their own pace, revisit misunderstood concepts and shift their focus to where they may need the most conceptual support.

In this article we assess the results of implementing our new e-learning system, designed as a formative teaching tool with the objective to provide factual knowledge and immediate results of formative assessments to students, including detailed explanations of the correct physiology after each assessment. The system has been designed to provide a student with experience in answering test questions relevant to their discipline, while explaining basic physiological concepts. Furthermore, our system is designed to provide SA students with knowledge applicable and relevant to the local population rather than information more relevant to North American or European populations, which are conventionally used. In this study, our objective was to assess the performance of students (summative assessment) after the introduction of an e-learning tool as a supplemental tool for learning and the subjective reactions of students to using such a tool.

Background

Students

The School of Physiology, University of the Witwatersrand, Johannesburg, SA teaches courses in physiology and medical biochemistry as compulsory components of 2nd-year undergraduate curricula in a range of different medical disciplines. These include pharmacy, physiotherapy, occupational therapy, nursing, dentistry, medicine, health sciences and biomedical engineering. The physiology course is divided into four 8 - 10-week blocks and is delivered through a series of lectures (5 hours per week), tutorials (3 hours per week) and practical laboratory skill sessions (3 hours per week). All lectures and tutorials are taught by academic staff members and practical sessions are demonstrated by trained postgraduate students under the guidance of academic staff members. The therapeutic health science course is taught to students studying pharmacy, physiotherapy, occupational therapy, nursing and dentistry as one class ($N=220$). Students write a summative test at the end of each of the four teaching blocks (based on the work covered in that quarter) and a final assessment at the end of the year (based on the course content taught throughout the year). The therapeutic health science course material includes the following: Test 1: blood, body fluids, immunology, metabolism, autonomic nervous system and excitable tissue; Test 2: metabolism, central nervous system and temperature regulation; Test 3: cardiovascular system, respiration, kidney, acid-base and gastro-intestinal system; and Test 4: liver, endocrine and exercise.

eEquip

In addition to lectures, tutorials and laboratory sessions, which were already in place, an e-learning initiative was introduced as a tool to supplement students' understanding of physiology and the method of assessment. eEquip (eQuestions for Understanding Integrated Physiology) is a custom-built e-learning platform to suit the specific needs of the school (developed by the school in collaboration with coding expertise supplied by an external information technology firm (Simnat Technology Pty Ltd, Johannesburg). The framework for the platform was based on the X-type multiple-choice questions (MCQs) used in our current assessments, developed by Mitchell.^[8] In our assessment protocol and eEquip program each MCQ statement has five corresponding responses, where each response must be answered as true or false. Each MCQ therefore contains five questions or statements that require an answer. In the eEquip program, once a question has been answered (true or false selected), the student is

given feedback on whether they were correct or incorrect. Additionally, an extensive explanation as to why the statement was true or false is presented to the student. Model answers have been researched and validated under the supervision of subject expert academic staff to align the model answers with current course content and objectives. Furthermore, images and explanations detailing the underlying mechanisms that explain the reasons for statements being correct or incorrect have been sourced, designed and included, enabling the students to visualise the rationale behind each statement. Selected responses also have links to approved internal library e-references or external sites (such as YouTube videos) that further clarify concepts. Therefore, eEquip was specifically designed and created to align the question types included in the program to be similar to those used in our current assessment protocols, providing experience in answering X-type MCQs and offering immediate feedback. The eEquip program draws on Kolb's experiential learning cycle, as it offers students the opportunity for concrete experience and active experimentation; the immediate feedback provides them with an opportunity for reflective observation and abstract conceptualisation.^[9]

The home page of eEquip is divided into 16 topics, reflecting the structure of the course topics taught throughout the year. There are approximately 500 MCQs with model answers captured in the system. A unique feature of the system is that many of the questions included are based on diseases or problems prevalent in patients seen in African hospitals. Thus, at an early point in their medical career, students are being exposed to problem-solving around problems and diseases such as malaria, HIV and kwashiorkor.

Methods

Study design

At the start of the academic year all the students who registered for therapeutic health sciences disciplines were given a brief orientation session to familiarise them with eEquip and encourage them to use the platform. Participation was voluntary and no extra credit incentives were offered to encourage use of the program. Students accessed eEquip using their personal student identification username and password. No time limitations were placed on answering the questions, as it was felt that this was a learning platform and students could take as much time as required to interact with the system. Because of internet security issues, the site was only accessible from computer laboratories at the university and students could not access the platform off campus.

Questionnaire

A paper-based questionnaire to obtain feedback about eEquip was administered to the students in the final lecture of the year as part of the department-approved course evaluation. This formed a convenience sample, as not the entire class was present. The students were asked to volunteer to complete the questionnaire and could elect to complete it anonymously. It was made clear to them that there was no obligation to complete the questionnaire and they would not be disadvantaged should they choose not to participate. The questionnaire administrators and e-learning team played no role in the summative assessment process. Using a 5-point Likert scale, eEquip-specific questions were answered on ease of access, frequency of usage, relevance of material and whether students were satisfied and would recommend the program. Furthermore, based on the questionnaire developed by Seluakumaran *et al.*,^[10] students were asked what the most useful features were.

Outcomes

Student logins to eEquip were tracked throughout the year to determine the percentage use of the program and the number of teaching blocks each student made use of. Fisher's exact 2×2 contingency tables were used to assess the relationship between students who passed and those who failed (50% cut-off) and their eEquip use per teaching block. Year-end grades (average of the results of the test at the end of each of the academic teaching blocks) were compared (using analysis of variance (ANOVA) with a Tukey's posthoc test) according to the number of teaching blocks where the student had made use of eEquip.

Results

Participants

The mean (SD) percentage of students who used eEquip throughout the year was 67 (6.9)%. A statistically significant percentage of students who passed used eEquip (62%), compared with only 25% of those who failed ($p=0.0036$). A significantly greater proportion of students who

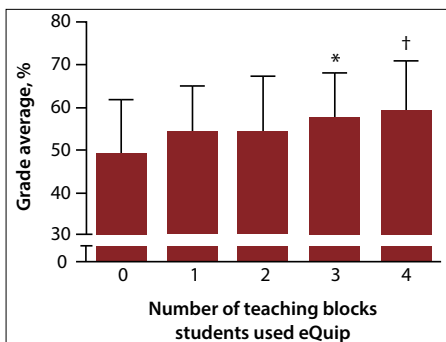


Fig. 1. Comparison between physiology year-end grade averages for therapeutic health science students based on the number of blocks for which the students used the e-learning tool eEquip (ANOVA, $p=0.0032$; Tukey's posthoc test, three blocks used v. eEquip not used ($*p<0.05$), four blocks used v. eEquip not used ($†p<0.01$)).

used eEquip in all four teaching blocks passed compared with those not making use of the program ($p=0.0006$; Table 1).

Students using eEquip for at least three academic blocks achieved significantly better year-end results than those who did not make use of the program (Fig. 1). Students were normally distributed in terms of grades achieved in the group using eEquip and those not using the program.

Questionnaire results

Completed questionnaires were received from 66% ($n=146$) of the class, and 92% of respondents stated that they had made use of eEquip at least once (Table 2). The students indicated that they made use of the e-learning tool most frequently immediately before tests.

Although 146 questionnaires were collected from the class, some of the respondents elected not to answer all the statements. Accordingly, each of the statements was calculated as a percentage of the responses for that statement (Tables 2 and 3). In each case ≤ 20 students failed to provide an answer to any question posed. Overall, feedback from the class was positive with regard to the registration process, access, ease of use, satisfaction and relevance of material on eEquip. Students found the MCQ model answers and images particularly useful, but provided mixed reactions about the links to other sites.

Discussion

Students who made use of eEquip achieved significantly better results in their summative tests than those who did not use the program, suggesting that the introduction of the online tool facilitated the learning process for students.

This study is congruent with numerous studies focusing on medical education, which have also demonstrated that students who participate in formative online assessments

and use supplementary tools performed better in summative tests and assessments.^[5-7,10-13] The significant differences in year-end results between the students who consistently used eEquip and those who did not may be a reflection of the higher percentage of use of the program and that students received greater benefit from the system. Kibble^[12] noted that students are less likely to participate in formative assessment tasks if participation is voluntary. Although the average use of the program throughout the year was $>60\%$, $\sim 13\%$ of the class reported that they had either not heard or made use of it, in the latter case primarily because access was restricted to on-campus use. Therefore, it is worthwhile noting that frequent promotion and accessibility are key features in the success of implementing an e-learning program.

Historically, students have struggled in the first tests in our 2nd-year physiology course, as they are introduced to a new question format and a more challenging course than they experienced during their 1st year of study. By modelling the question type included in the e-learning program on the assessment protocol, students were familiarised with the question format when using the online system before writing the test, which may have assisted them when writing the summative assessments. Familiarisation with the question format highlights one of the strengths of eEquip, which exposes students to the question type and expectations in answering styles, thus providing them with experience with the question type. Previous literature has shown formative assessments (such as our eEquip-based questions) to be most effective if they are similar to the summative assessments that they are supporting.^[5,14]

Features of the eEquip system that we considered key to the successful implementation of our formative e-learning tool included the creation of a system that encouraged the learning process and provided timely and

Table 1. Students who passed or failed 2nd-year physiology according to the number of teaching blocks for which they used the e-learning program eEquip

Number of teaching blocks students used eEquip, <i>n</i>	Students who passed, %	Students who failed, %
0	6	7
1	5	4
2	12	7
3	15	5
4*	31	8

* $p=0.0064$ v. 0 (Fisher's exact test).

Table 2. Summary of student feedback with regard to the use of eEquip

Did you make use of eEquip?	Students, %
I looked at it once	5
I used it just before tests	49
I consistently used it	38
I knew about it but I never used it	5
What is eEquip? I've never heard about it or used it	3

Table 3. Summary of therapeutic health science students (physiology) feedback with regard to eQuip, provided by a questionnaire using a condensed Likert scale

Student feedback	Students, %		
	Agree	Neutral	Disagree
The registration process for eQuip was easy	87	9	4
eQuip was easy to access	71	14	16
I was happy and satisfied to use eQuip	91	5	4
eQuip was easy to navigate and use	93	4	2
The material on eQuip was relevant and appropriate	94	5	1
eQuip helped me to further my understanding about the topic taught in physiology	90	7	2
eQuip complemented traditional learning through lectures and tutorials	84	14	1
I recommend the School of Physiology to continue using eQuip	96	1	3
I don't think I learnt much from eQuip	5	13	82
I like reading notes/textbooks rather than using eQuip	11	28	60
eQuip motivated me to learn	61	31	8
The most useful features of eQuip			
Model answers to each question	97	3	0
The images	84	12	4
That it allowed me to practise MCQs, but wasn't for marks	92	7	1
Easy access to the model answers	91	8	2
Links to other sites	47	30	23

informative feedback. Marden *et al.*^[15] reported that formative learning tools were more useful when students were allowed multiple unsupervised and untimed attempts. Therefore, another strength of e-Quip is that it creates a non-intimidating environment for students to assess and re-assess their knowledge and practise questions. Furthermore, to facilitate student understanding and foster a student's sense of responsibility for their learning, it was seen as beneficial that our formative assessment provides informative and supportive feedback, rather than just a grade, and does so in a timely manner to optimise learning outcomes.^[16,17]

We cannot definitively state that the higher results obtained by eQuip users compared with the results of those who did not use the program were because more conscientious students made use of the system and whether they would have obtained such results without the program. However, the distribution curves of the grades for students who used the system and those who did not indicate that there was an even distribution of strong and weak students. Two studies by Kibble *et al.*^[11,13] demonstrated that students were more likely to participate in formative assessment tasks if

there were extra credit incentives. However, as noted by Kibble, increasing incentives to participate may result in a disconnect between the final grades and the amount of online participation. If incentives are offered, the motivation for using the program may not be the attainment of knowledge but rather to achieve the necessary grades.

In contrast to incentive-driven engagement with a formative assessment tool, voluntary participation in formative assessment tasks is more likely a reflection of self-directed learning. Our students had the freedom to access information from a reliable source at their convenience (albeit limited to on-campus access) and they could control the amount of in- and output that they obtained, essentially empowering them to take control of their learning. Self-directed learners are able to identify their own deficits and make amends. eQuip lends itself to this, as it allows students to work at their own pace and apply information. This is particularly useful in the local setting, as the majority of the class are second-language learners (not learning in their mother tongue).

Conversely, it is possible that the easy access to answers on eQuip may actually facilitate a

lack of self-directed learning. The results from the questionnaire indicated that students were motivated to use eQuip, as the system provided them with easy access to model answers, which the students rated as particularly useful. It is possible that students viewed the system as a means to attaining the correct answers and not as a learning tool. Taradi *et al.*^[18] captured this idea by stating 'the real power of computers to improve education will only be realized when students actively use them as cognitive tools rather than passively perceive them as tutors or repositories of information.'

The mixed student reaction to the additional resources supplied supports the notion that students may have used eQuip merely as an information repository. We expected that the additional resources would guide students to further their knowledge and correct misconceptions through their own learning process. However, <50% of students agreed that the links to other sites were useful. We speculate that the students may have considered it too much effort to access the additional material or that this information was superfluous to the content provided by their lecturers. Further investigation into reasons why these resources were not utilised and which resources were used is required.

Study limitations

Results from our questionnaire survey found that students complained about access to the system being limited to computer laboratories on campus and felt that they would have used the program more often if they could have accessed it from their home environment, an issue which we have subsequently addressed and rectified. Additionally, technical difficulties with access to the system were resolved when students reported such issues. As access to the system is a fundamental requirement for compliance, the provision of technical assistance (in our case, by making the contact details of the system administrator available to students) is vital to its success. The study design could not control for potential confounding variables regarding the study population. We previously stated that the higher grades obtained by eQuip users could have been because the more conscientious students made use of the system and would, regardless, have obtained higher marks; this should be considered a limitation. Moreover, the motivating factors and likelihood to commit to learning in an online environment were not

considered in this study, which is a potential limitation and requires further research.

Conclusion

The implementation of a physiological e-learning program was related to improved summative assessment performance in a cohort of undergraduate students; however, improvements are only evident with frequent use. These results are consistent with those in the literature, which recommend the use of active online learning tools to promote educational performance. Results from a questionnaire assessing the students' experiences suggested that the program was found to be a useful and relevant addition to our undergraduate physiology courses. Recommendations include further research into the additional resources the students are utilising and motivations behind committing to online learning tools. Moreover, encouraging students to frequently use the platform and take responsibility for their learning should further improve performance.

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References

- Gorman PJ, Meier AH, Rawn C, Krummel TM. The future of medical education is no longer blood and guts, it is bits and bytes. *Am J Surg* 2000;180:353-356. [[http://dx.doi.org/10.1016/S0002-9610\(00\)00514-6](http://dx.doi.org/10.1016/S0002-9610(00)00514-6)]
- Aldridge JM, Laugksch RC, Fraser BJ. School-level environment and outcomes-based education in South Africa. *Learning Environments Research* 2006;9(2):123-147. [<http://dx.doi.org/10.1007/s10984-006-9009-5>]
- Etyang AO, Scott JAG. Medical causes of admissions to hospital among adults in Africa: A systematic review. *Glob Health Action* 2013;6(1):1-14. [<http://dx.doi.org/10.3402/gha.v6i0.19090>]
- Michael J. Where's the evidence that active learning works? *Adv Physiol Educ* 2006;30:159-167. [<http://dx.doi.org/10.1152/advan.00053.2006>]
- Dobson JL. The use of formative online quizzes to enhance class preparation and scores on summative exams. *Adv Physiol Educ* 2008;32:297-302. [<http://dx.doi.org/10.1152/advan.90162.2008>]
- Olson BL, McDonald JL. Influence of online formative assessment upon student learning in biomedical science courses. *J Dental Educ* 2004;68:56-65.
- Velan GM, Jones P, McNeil HP, Kumar RK. Integrated online formative assessments in the biomedical sciences for medical students: Benefits for learning. *BMC Med Educ* 2008;8:52. [<http://dx.doi.org/10.1186/1472-6920-8-52>]
- Mitchell G. *Medical Physiology: Objectives and Multiple Choice Questions*. 2nd ed. Durban: Butterworths, 1986.
- Kaufman DM, Mann KV. Theory and learning in medical education: How theory can inform practice. In: Swanwick T, ed. *Understanding Medical Education. Evidence, Theory and Practice*. London: Wiley Blackwell, 2014.
- Seluakumaran K, Jusof FF, Ismail R, Husain R. Integrating an open-source course management system (Moodle) into the teaching of first-year medical physiology course: A case study. *Adv Physiol Educ* 2011;35:369-377. [<http://dx.doi.org/10.1152/advan.00008.2011>]
- Kibble J. Use of unsupervised online quizzes as formative assessment in a medical physiology course: Effects of incentives on student participation and performance. *Adv Physiol Educ* 2007;31:253-260. [<http://dx.doi.org/10.1152/advan.00027.2007>]
- Kibble JD. Voluntary participation in online formative quizzes is a sensitive predictor of student success. *Adv Physiol Educ* 2011;35:95-96. [<http://dx.doi.org/10.1152/advan.00053.2010>]
- Kibble JD, Johnson TR, Khalil, MK, et al. Insights gained from analysis of performance and participation in online formative assessment. *Teach Learn Med* 2011;23(2):125-129. [<http://dx.doi.org/10.1080/10401334.2011.561687>]
- Rolfé I, McPherson J. Formative assessment: How am I doing? *Lancet* 1995;345:837-839. [[http://dx.doi.org/10.1016/S0140-6736\(95\)92968-1](http://dx.doi.org/10.1016/S0140-6736(95)92968-1)]
- Marden NY, Ulman LG, Wilson FS, Velan GM. Online feedback assessments in physiology: Effects on students' learning experiences and outcomes. *Adv Physiol Educ* 2013;37:192-200. [<http://dx.doi.org/10.1152/advan.00092.2012>]
- Gipps V. What is the role for ICT-based assessment in universities? *Studies in Higher Education* 2005;30(2):71-180. [<http://dx.doi.org/10.1152/advan.00092.2012>]
- Hattie J, Timperley H. The power of feedback. *Rev Educ Res* 2007;77(1):81-112. [<http://dx.doi.org/10.3102/003465430298487>]
- Taradi SK, Taradi M, Radić K, Pokrajac N. Blending problem-based learning with Web technology positively impacts students learning outcomes in acid-base physiology. *Adv Physiol Educ* 2005;29:35-39. [<http://dx.doi.org/10.1152/advan.00026.2004>]