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Can multiple choice questions assess application of knowledge in pharmaceutical science teaching?

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Abstract

Introduction: Application of knowledge is the required attribute of graduates from pharmacy schools in Australia and worldwide.

Aim: This paper describes a study, which examines the use of multiple-choice questions (MCQs) to assess the application of knowledge in two Pharmacy courses.

Methodology: Seventy-three MCQs were ranked independently in a 'blind' manner as knowledge recall (K) or application of knowledge (A). The ranked MCQs were then included in the final exams of the Pharmaceutics and Medicinal Chemistry courses. The differences in the percentage of students who obtained a correct answer for each of the types of MCQ were then analysed using Student's *t*-test.

Results: No differences were observed in the percentage of students who obtained a correct answer for all MCQs compared to the percentage of students who obtained a correct answer for A or K MCQs in the Medicinal Chemistry exam. For the Pharmaceutics exam, significant differences were observed between the percentage of students who obtained a correct answer for all MCQs compared to the percentage of students who obtained a correct answer for A MCQs (p=0.012).

Conclusion: This is a primary study in the use of MCQs to assess the application of knowledge, and its findings indicated that great disparity in allocation of A versus K MCQs often exists between academics, which could have a profound impact on the overall outcomes of such study.

Keywords: *Assessment, Application Of Knowledge, Multiple Choice Question, Higher Cognitive Thinking, Pharmaceutical Science*

Introduction

Application of knowledge is one of the core attributes of graduates from pharmacy schools in Australia and worldwide. For all pharmacy schools in Australia, the graduate qualities or 'attributes', which consistently encompass problem-solving skills, align well with the precisely articulated goal of educating prospective pharmacists who are expected to have both sound pharmaceutical knowledge and a set of skills to enable effective and safe professional practice. Problem solving will require that graduates are able to apply, analyse and synthesise information. The Pharmaceutical Society of Australia in 'Competency Standards for Pharmacists' (Competency Standards for Pharmacists in Australia, 2016; p.19) has highlighted within their key statement for the profession "effective communication, organisational and interpersonal skills, effective reasoning, judgment, analytical and problem solving skills, with an ethical and professional attitude …" as essential to the profession of pharmacy. The Graduate Attributes of the Australian Undergraduate Pharmacy Programme are set and reviewed by The Australian Pharmacy Council, who approves and provides accreditation to pharmacy programmes within Australia.

An early study conducted in the School of Pharmacy and Medical Sciences, The University of South Australia had reported the use of multiple-choice questions (MCQs) as a feasible approach to assess the application of knowledge in pharmacology courses (Stupans, 2006). This article describes a study, which examines the use of MCQs to assess the application of knowledge in two pharmaceutical courses of the Pharmacy programme in the Northern Territory, Australia. Studies to examine the use of MCQ-format to assess higher cognitive thinking skills in pharmacy teaching other than in pharmacology courses will be of important value, as MCQs would offer an ideal assessment approach to assess large quantities of course materials.

It has been well reported that MCQs can be used successfully to assess 'body of knowledge' or knowledge recall in pharmacology teaching (Stupans, 2006). MCQ-format offers an effective approach to assess a large content of course materials and provides quick results as

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MCQs can be marked electronically (Collins, 2014; Pugha *et al*., 2016). It is feasible to design well-constructed MCQs for assessing higher cognitive thinking based on cognitive models, which are currently available (Case & Swanson, 2002; Touchie, 2010; Haladyna, 2013; Collins, 2014; Pugha *et al*., 2016). Examples of such cognitive models include the Millers triangle (Millers, 1990) and Bloom's taxonomy (Bloom *et al*., 1956). Traditionally, Miller's pyramid comprised of four levels of cognitive thinking, including 'knows', 'knows how', 'shows how', and 'does'. Recently, two more underpinning awareness levels that often occur before we 'know' have been suggested to be included in the Miller's pyramid, which included 'heard of' and 'knows about'. The first two stages, 'knows' and 'knows how', can be practically assessed using the traditional assessment tools of oral tests or written exams such as MCQ exams (Millers, 1990). While 'knowing' and 'knowing how' might not always necessarily extrapolate to the application of knowledge in clinical settings, they can feasibly extrapolate to the application of knowledge in teaching and learning assessments.

Recent study by Zaidi and colleagues (2017) has shown that Bloom's taxonomy has been used to identify MCQs that assess students' critical thinking skills and provided good evidence suggesting that higher-order MCQs support a deeper conceptual understanding of scientific knowledge process skills. Moreover, the use of automatic item generation, in which computer technology is used to develop MCQs from cognitive models has also been shown to produce MCQs with psychometric properties comparable to those generated using a traditional approach and can be used to assess higher order skills or 'application of knowledge' (Pugha *et al*., 2016).

While the use of MCQs to assess higher cognitive thinking has been explored and also applied widely in undergraduate, post-graduate medical teaching and board examinations, few studies have been conducted in pharmacy to investigate the use of MCQs to assess higher cognitive thinking (Stupans, 2006; Palmer & Devitt, 2007). While Stupans' study focussed on the assessment of application of knowledge by local students versus international students, the study by Palmer & Devitt compared MCQs versus written essay to assess higher cognitive thinking in medical and surgery teaching. The current study is the first study in the last decade, which seeks to evaluate the use of MCQ-format to assess the application of knowledge of pharmaceutical science subject materials in pharmacy, with a focus on local students.

Methods

MCQs were developed and ranked as knowledge recall (K) or application of knowledge (A), based on different levels of cognitive thinking as defined in the literature (Mislevy *et al*., 2000; Case & Swanson, 2002; Palmer & Devitt, 2007; Freiwald *et al*., 2014). The MCQs were ranked independently by the academic staff responsible for the delivery of the corresponding lecture contents (Staff 1) and by two other academic staff in a 'blind' manner as previously described (Stupans, 2006). These two academic staff had taught in the Pharmacy programme, but did not teach these courses and did not deliver the corresponding lecture material (Staff 2 and 3). All academics were advised not to discuss their allocation of K MCQs versus A MCQs with other staff.

Selected MCQs were included in the final examinations of two pharmacy courses, namely Pharmaceutics, and Medicinal Chemistry and Pharmacogenetics. The course Pharmaceutics was one of four core subjects being offered in the 3rd year of the programme, which covered more advanced knowledge on drug delivery systems, their clinical uses and application. The course Medicinal Chemistry and Pharmacogenetics was one of the four key subjects being delivered in the 2nd year of the programme, which consisted of both basic and advanced medicinal chemistry knowledge. A total of 37 MCQs were used in the Medicinal Chemistry and Pharmacogenetics exam. Thirty-six MCQs were included in the Pharmaceutics exam. The exams were then administered to the 3rd year and 2nd year pharmacy students, respectively of the pharmacy programme at Charles Darwin University (CDU), Northern Territory, Australia. The 3rd year pharmacy students involved in this study were the first 3rd year student cohort of the CDU Pharmacy programme, which achieved full accreditation in 2009. The study was approved by the Pharmacy Discipline, School of Environmental and Life Sciences, Charles Darwin University.

In the current study, all MCQs were validated based on the analysis of the students' overall results, in which each of the questions was expected to provide the percentage of students selecting the correct answers between 20%-80% (Case & Swanson, 2002; Freiwald *et al*., 2014). All MCQs that were included in the two exams met this criterion. Examples of K versus A MCQs are provided in the Appendix. The selected MCQs used in this study had also been previously developed for final exams of similar courses, and had been used previously in the final exams of these courses for a Pharmacy programme at a different university. The use of these MCQs had not been analysed previously.

Statistical analyses of the students' results in the two exams were performed using Student's *t*-test. The differences in the percentage of students who obtained a correct answer for all MCQs, compared to the percentage of students who obtained a correct answer for K MCQs and the percentage of students who obtained a correct answer for A MCQs were considered to be significant at $p<0.05$.

Results

Analyses of the data obtained for the two exams, with the percentages of students who obtained a correct answer for each type of the questions are shown in Table I. The percentage of students who obtained a correct answer for K MCQs compared to that of students who obtained a correct answer for A MCQs are also shown.

Table I: Data (presented as mean ± SD) showing percentages of students who obtained a correct answer for each type of MCQs

Exams	Med Chem PGx Exam (2nd Year Pharmacy)	*p*-values	Pharmaceutics Exam (3rd Year Pharmacy)	*p*-values
(%) Correct all MCQs All MCQs number (No)	66.22 ± 26.00 37		60.86 ± 26.51 36	
(%) Correct K MCQs (Staff 1, 2) K MCQ No	68.75 ± 11.62 20	0.149[a]/0.098[b]	67.68 ± 15.48[#] 18	0.198[a]/0.024[b]
(%) Correct K MCQs (Staff 3) K MCQ No	65.64 ± 12.10 26	0.308[a]/0.472[b]	61.29 ± 14.99[#] 31	0.472[a]/0.015[b]
(%) Correct A MCQs (Staff 1, 2) A MCQ No	63.24 ± 12.06 17	0.469[a]	54.04 ± 15.13 18	0.145[a]
(%) Correct A MCQs (Staff 3) A MCQ No	64.48 ± 16.80 11	0.311[a]	78.18 ± 18.88 5	0.012[a]

[*]Statistical analysis was performed using Student's *t*-test, the difference was considered to be significant at $p<0.05$
[a]Compared to percentage of students obtained a correct answer for all MCQs
[b]Difference in the percentage of students obtained a correct answer for K MCQs compared to that of students obtained a correct answer for A MCQs.
[#]Statistically significant at $p<0.05$ compared between the percentage of students obtained a correct answer for K MCQs versus that of students obtained a correct answer for A MCQs.

As shown in Table I, for the Medicinal Chemistry and Pharmacogenetics final exam, no significant differences were observed in the percentage of students who obtained a correct answer for all MCQs compared to the percentage of students who obtained a correct answer for K MCQs. Similarly, the percentage of students who obtained a correct answer for K MCQs was not significantly different to the percentage of students who obtained a correct answer for A MCQs ($p>0.05$). The mean percentage of students who obtained a correct answer for all 37 MCQs was 66.22%, Standard Deviation (SD) was 26.00, whereas the mean percentage of students who obtained a correct answer for A MCQs was 63.24% (SD = 12.06), 64.48% (SD = 16.80), (ranked by Staff 1, 2 versus Staff 3, respectively), and that of students who obtained a correct answer for K MCQs was 68.75% (SD = 11.62), 65.4% (SD = 12.10).

For the Pharmaceutics exam, the mean percentage of students who obtained a correct answer for all 36 MCQs was 60.86% (SD = 26.51) whereas that of students who obtained a correct answer for K MCQs was 67.68% (SD = 15.48) versus 61.29% (SD = 14.99) (ranked by Staff 1 and 2 versus Staff 3 respectively) ($p>0.05$). A significant higher mean percentage of students who obtained a correct answer for A MCQs (ranked by Staff 3) compared to that of students who obtained a correct answer for all 36 MCQs was obtained, which was 78.18% (SD = 18.88) ($p=0.012$, reached statistical significance at $p<0.05$).

Overall, for MCQs allocated by Staff 1 and 2, compared to the 2nd year student results, the percentage of students who obtained a correct answer for A MCQs in the 3rd year exam was lower, which was unexpected. As 3rd year students have already been taught both basic and applied Pharmaceutics in the 2nd year, and these student are more advanced stage students currently in their final year of the programme, it would be fair to expect that they should perform better in critical thinking skills, compared to more junior 2nd year students. For MCQs allocated by Staff 3, compared to the 2nd year student results, the percentage of students who obtained a correct answer for A MCQs in the 3rd year exam was higher, which was as expected.

In addition, great disparity in the allocation of A versus K MCQs was observed in both exams, with 13 more MCQs allocated as A in the 3rd year exam and 6 more MCQs allocated as A in the 2nd year exam by Staff 1 and 2 compared to Staff 3. This was not expected. Moreover, it might not be ideal to complete the comparison based on different number of questions allocated to A and K. This disparity and how it may have affected the overall results are further discussed below.

Discussion

It has been well reported that MCQs can be used successfully for assessing students' body of knowledge in both pharmacy and other related disciplines. Whether MCQs can also be used successfully for assessment of higher cognitive thinking skills is currently not well documented. Although this has been well explored in medical teaching and medical board examinations, little information is available in pharmacy literature. The current study is the first to investigate the use of MCQ-format for assessments of pharmaceutical science subject materials.

In the Medicinal Chemistry and Pharmacogenetics exam, the finding that there were no significant differences in the percentage of students who obtained a correct answer for MCQs that were allocated as K compared to the percentage of students who obtained a correct answer for MCQs that were allocated as A was consistent with previous studies. For example, Stupans (2006) had reported that MCQs designed as A provided consistent results to MCQs aimed to assess K. The findings in this study showed good evidence that MCQs can assess higher cognitive thinking, rather than just recall or memorising skills. The study by Stupans also found the disparity in questions allocated as A or K could result in greatly inconsistent findings and it is extremely difficult to draw firm conclusions. This was also consistent with the results of the current study. While Stupans' study compared critical thinking skills between international versus local students in pharmacology teaching, with a slight focus on English proficiency, the current study examined the use of MCQs to assess the A in pharmaceutical courses, with a focus on local pharmacy students. Another previous study had also examined MCQs to assess higher cognitive thinking (Palmer & Devitt, 2007), however this study compared MCQs to essay writing, which is not the same objective as that of the current study.

In the current study, a marked difference in the allocation of A MCQs versus K MCQs between staff was observed in the Pharmaceutics exam. A total of 18 MCQs were ranked as A by two academics, whereas, only five MCQs were ranked as A by the other staff. Although these five A MCQs were among those 18 A MCQs ranked by the two academics, this raises considerable concerns as to whether the great disparity in K versus A MCQs ranking may have affected the overall assessment of the Pharmaceutics exam.

A significant difference in the mean percentage of students who obtained a correct answer for A MCQs compared to that of students who obtained a correct answer for K MCQs was also observed in the Pharmaceutics exam. The students' overall results for this exam were also inconsistent. These inconsistent findings possibly resulted from the marked differences in the allocation of A versus K MCQs in this exam. Thus further follow-up studies to standardise the allocation of A versus K MCQs would be critically important. For the Medicinal Chemistry and Pharmacogenetics exam, the disparity in K MCQs versus A MCQs allocation between academics also existed, however it was much smaller compared to that for the Pharmaceutics exam. A total of 17 MCQs were ranked as A by two academics, whereas, 11 MCQs were ranked as A by the other staff. These 11 A MCQs were among those 17 A MCQs ranked by the two academics. However, the students' overall results in this exam were consistent for all types of MCQs, it is unlikely that the disparity in K MCQs versus A MCQs ranking affects the overall MCQ-format assessment of this exam. Thus, the finding further reinforces the importance of setting clear criteria for MCQs, which aim to assess the A.

Conclusion

Collectively, this is a primary study in the use of MCQs to assess the A, and its findings indicated that great disparity in allocation of A versus K MCQs often exists between academics, which could have a profound impact on the overall outcomes of such a study. In order to obtain consistent results and to expand this research area further, it is recommended that the following aspects be considered for future work, including a higher number of academics involved in ranking A versus K MCQs, a higher number of students in class, as well as testing different students cohorts, for example testing students enrolled in the same courses in two or three follow-up years. More importantly, cognitive models such as Miller's triangle or Bloom's taxonomy should be used or applied as a guild for collaborative discussion and agreement between academics. Further more, clear criteria should be set to standardise MCQs that aim to assess the application of knowledge and the developed MCQs to be evaluated or at least tested to ensure consistency prior to implementation in tests and exams.

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Declaration of interest

The authors report no declarations of interest.

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Appendix

<u>Examples of AK MCQs included in the two exams:</u>

Q1. Chloramphenicol succinate was developed as a pro-drug of chloramphenicol. The primary justification for its use in parenteral formulations is:

a) It is more stable (than chloramphenicol) to chemical degradation.
b) It is more soluble (than chloramphenicol) and therefore more readily given as an intravenous injection.
c) It slowly degrades to chloramphenicol, providing a sustained action.
d) It is less likely (than chloramphenicol) to cause thrombophlebitis upon injection.
e) Using the succinate enables the injection to be made isotonic.

Q2. A drug company has recently identified and a new protein that they believe is an ideal drug target for the treatment of hypertension. In the era of pharmacogenomics ONE of the first investigations that should be undertaken by the company is which of the following?

a) Investigation for the gene that encodes for the drug target for genetic variability.
b) Investigation for the gene that encodes for the drug metabolising enzyme for genetic variability in toxicity.
c) Investigation for the gene that encodes for the drug metabolising enzyme for genetic variability in drug response.
d) Investigation for the gene that encodes for the drug metabolising enzyme for genetic variability in drug metabolism.
e) Investigation for the gene that encodes for both the drug target and other related molecular targets for genetic variability.

Q3. A patient who received a renal transplant has been treated with cyclosporine to prevent the rejection of the organ. Cyclosporine is metabolised by CYP3A. The patient is also being treated with diltiazem that is a known inhibitor of CYP3A. The patient would like to start taking St. John's Wort for his mild depression. St. John's Wort is a known inducer of CYP3A. Which of the following best describes the potential drug interactions between cyclosporine and St John's Wort?

a) There is no concern regarding the coadministration, as there is no interaction between cyclosporine and St John's.
b) There is no concern regarding the coadministration as the patient is also being treated with a CYP3A inhibitor.
c) The patient should not start taking St John's wort as it will decrease cyclosporine concentration due to the decrease in its metabolism and as a result, the patient is at significant risk of transplant rejection.
d) The patient should not start taking St John's wort as it will increase cyclosporine concentration due to the decrease in its metabolism and as a result, the patient is at significant risk of transplant rejection.
e) The patient should not start taking St John's wort as it will decrease cyclosporine concentration due to the increase in its metabolism and as a result, the patient is at significant risk of transplant rejection.

<u>Examples of KR MCQs included in the two exams:</u>

Q1. Which one of the following drugs has been marketed in the form of a 'lollipop' for transmucosal delivery?

a) Scopolamine
b) Glyceryl trinitrate
c) Midazolam
d) Fentanyl
e) Pilocarpine

Q2. Phase I drug metabolism reaction include:

a) Oxidation and methylation
b) Oxidation and acetylation
c) Hydrolysis and oxidation
d) Reduction and sulphation
e) Oxidation and glucuronidation

Q3. CYP2C9 refers to:

a) The gene for a cytochrome P450 belonging to superfamily 2, subfamily C.
b) The gene product for a cytochrome P450 belonging to family 2, subfamily C.
c) The gene for a cytochrome P450 belonging to superfamily 2, family C, subfamily 9.
d) The gene for a cytochrome P450 belonging to family 2, subfamily C.
e) The gene product for a cytochrome P450 belonging to superfamily 2, family C, subfamily 9.