

One size does not fit all in the assessment of pharmacology learning in a diverse multidisciplinary undergraduate student class

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ABSTRACT

Background: Assessment not only drives student learning but is also an indicator of the success of teaching methodologies employed. There is considerable pressure on pharmacology instructors to effectively teach the discipline to diverse multidisciplinary (biochemistry, chemistry, physiology, and medicine) undergraduate students. To date, there are no studies documenting and assessing pharmacology learning in the aforementioned group. This is an 8 years retrospective study aimed at compiling, analyzing, and evaluating different types of assessment to gauge multidisciplinary student learning in pharmacology.

Methods: Quantitative and qualitative (rather than single) methods of data collection were used to provide a richer and mutually corroborative array of evidence. Assessment of student learning included computer-based assessment (CBA) of laboratory practicals, end of the module (EOM) multiple choice questions (MCQ) examination and an EOM essay paper.

Results: Our findings indicate significant variation in students' scores depending on the type of assessment employed. Strikingly over the 8-year period annual mean scores in the physiology student cohort were consistently and significantly lower compared to other groups. This contrasts with the medical student cohort who demonstrated a consistent and significant increase in mean scores compared to overall class means. Interestingly, no deviations were observed in the overall CBA, MCQ scores among all student groups. However, on closer analysis laboratory practical type influenced student performances with lower scores in the computer-assisted learning (CAL) CBA versus the wet laboratory practical CBA.

Conclusion: Our research-based evidence suggests that certain modes of assessment may preferentially suit some but not all students from multidisciplinary backgrounds within the one pharmacology class.

Keywords: Pharmacology, Assessment, Multidisciplinary student groups

INTRODUCTION

Pharmacology is a subject that is integral to the studies of many health science students. It is essential not only for students who will be involved in clinical practice but also for those involved in the biological sciences.^{1,2} In general, students find pharmacology difficult with information overload a common complaint owing to increased drug development and the volume of associated scientific information.³ However, the quality of pharmacology undergraduate education is vitally important whether students are preparing for a career in science or transitioning to medical or graduate school. There is to date

a paucity of studies investigating effective pharmacology teaching, learning, and assessment for multidisciplinary students within the same pharmacology classroom.^{4,5} Different methodologies have been reviewed for teaching pharmacology to medical, dental, and nursing students⁶ but analysis of effective assessment to gauge student learning in a multidiscipline environment is clearly lacking.

Assessment has been identified as probably the most important event to aid student learning and is a fundamental component of teaching and learning.⁷ Assessment and evaluation form an integral part of the total evaluation process. It is a continuous activity which should be designed

simultaneously with curriculum development. Due to recent modularization of degree programs it is not uncommon to find students from diverse backgrounds within the one pharmacology class. It is unfortunate that modularization has meant that many students are examined only in the end of module (EOM) assessments which has been described as linear with little involvement and engagement by the students.⁸ It is now becoming apparent that continuous assessment in conjunction with EOM assessment is necessary for both teacher and students to evaluate progress and success in the attainment of the teaching and learning objectives.

Assessment is continuously changing as it is aligned with the changes implemented in both teaching and learning. Traditional modes of assessment have included written assignments, time-constrained examinations, essays and reports that in many instances merely test students on factual recall. It is now becoming clearer that assessment must be fit-for-purpose enabling measurement of the extent to which students have learned together with measuring the extent with which they can demonstrate their learning.⁹ Thus, newer modes of assessment focus on an evidence of student achievements such as portfolios, role-plays, case-based studies, oral, and poster presentations rather than on merely regurgitation of memorized facts and figures.¹⁰

In particular, assessment in pharmacology has included conventional educational methods such as theory writing and *viva voce*.¹¹ However, such techniques may only assess rote recall of facts, leading to students adopting a surface learning style that relies purely on memorization. In contrast, if students are assessed on how they integrate, interpret and apply information then they will adopt a different strategic learning style to obtain success. Thus, more innovative methods such as problem-based learning^{12,13} research critic and team assessment¹⁴ have been looked at in assessing student knowledge and understanding in pharmacology.

This is the first retrospective study assessing both qualitative and quantitative methods of assessment to ascertain whether student learning in pharmacology varies between multidisciplinary groups. Overall our analysis and findings have provided evidence-based research that the way we assess our students from multidisciplinary backgrounds may not be appropriate for all. Our work has now afforded us the opportunity to evaluate our existing assessment techniques with a view to providing an assessment that is fit-for-purpose for all students in the near future.

METHODS

Participants

This paper reports on an observational, retrospective study that focuses on undergraduate pharmacology students from four different disciplines (biochemistry, chemistry,

physiology, and medicine) over an 8-year period (from academic year [AY] 06/07 to 13/14). All students had previously completed a pharmacology module prior to enrollment in this module. All science students in this study were Irish; the majority (71%) of medical students were Irish with the balance being non-EU students. The medicine student cohort was in their 2nd year of study while all others were in their 3rd year. Mean annual student enrolment numbers were 78.6 ± 7.9 comprising biochemistry (12.6 ± 1.5), chemistry (18.1 ± 1.7), physiology (24.1 ± 3.2), and medicine (23.8 ± 1.5). In general, female students formed a larger cohort of the class with $62 \pm 3.9\%$ of females present annually. Of note, the medicine student cohort was not part of the overall class for AY12/13.

Assessment methods

Both quantitative and qualitative methods were used to assess multidisciplinary student learning in pharmacology. In this report, four different approaches were used to assess students' learning in pharmacology: (i) wet and dry practical related computer-based assessments (CBA) comprising multiple choice questions (MCQs), (ii) an EOM MCQ, (iii) a final written essay paper, and (iv) EOM questionnaire.

Practical classes

Design: students completed three different laboratory practicals which were strategically positioned within the module to follow four traditional didactic lectures covering the theory of related pharmacological topics. In the two wet practicals, students apply their knowledge in a practical context in the laboratory.^{15,16} Conversely, the computer-assisted learning (CAL) practical provided a dry laboratory experience where experimental software is utilized to understand and reinforce concepts and techniques covered in didactic lectures.¹⁷ Conducting: students were paired for the two different wet laboratory practicals but not for the simulated human pharmacology practical. Students were given 2 hrs to complete each of the three practicals which were held on separate weeks. CBA: effective assessment of laboratory practicals is a constant challenge for large-size classes. To reduce the workload involved for teachers but without compromising the student learning experience CBA was utilized.¹⁸ In this instance, CBA was limited to MCQ format (described below). All students used their student registration number and university username to access the CBA from any internet-linked computer.

MCQ examinations

MCQs are routinely used in departmental examinations or as summative EOM examinations.¹⁹ In this report student performances in pharmacology, MCQs were explored in two different assessments. First, CBA MCQs were completed by students in their own time following attendance and

completion of each practical session. CBA MCQs comprised 30 single-best answer questions consisting of a stem and five completing phrases. Only one submission a student was permitted. It was not a timed event, but submissions were not allowed the following the 1 week deadline after website activation. Second, the 1 hr EOM MCQ consisted of 20 questions containing five true/false statements. This was a timed exam of 1 hr duration. Construction of MCQs: the MCQs were designed based on the application of Bloom's taxonomy²⁰ testing students' rote recall, comprehension, application, analysis, synthesis and evaluation. Of note, the various levels of Bloom's taxonomy are not always directly analogous to degrees of difficulty.²¹ Questions were written by the sole teacher of the module and vetted by another within the Department of Pharmacology for content accuracy. Each individual CBA MCQ was based on the preceding four traditional didactic lectures in addition to the specific practical performed. In contrast, the EOM MCQ was based on the entire module (18 lectures) and the three practical sessions combined.

Final EOM essay written assessment

Students from all four disciplines sat the final written assessment after completion of the module. The format of the examination was six questions given to answer three, each question also contained an internal choice. It was a timed examination of 1 hr and a half in duration. Staff scoring student answers were blinded to the identity of the student as well as student discipline.

EOM questionnaire

The written questionnaire is a powerful tool in research.²² An EOM anonymous questionnaire was designed to assess student feedback on teaching, learning, and assessment methods. Students from all four disciplines completed the on-line questionnaire in their own time with a limit of 1 month for completion following the EOM. The questionnaire consisted of a mix of statements with students indicating whether they strongly agreed, agreed, were neutral, disagreed, or strongly disagreed with each statement. In addition, the questionnaire invited qualitative comments from students on their experiences of the CAL and wet laboratory practicals.

Data preparation and analysis

Data were analyzed statistically to find out correlation outcome(s) between written and MCQ examinations and between wet and dry practical CBAs. Pearson's correlation coefficient (r value) was estimated using the Pearson's product-moment method.²³ The r value is a numerical value between -1 and 1 that expresses the strength of the linear relationship between two variables. When r is closer to 1 it indicates a strong positive relationship. A value of 0

indicates that there is no relationship. We also investigated whether there were any overall differences in exam scores between the four independent discipline groups for each assessment. Student's t -test and the ANOVA test were used to compare exam performance by multidisciplinary student groups in pharmacology. As the results were in agreement using both methods, only results for the Student's t -test are shown. In addition, we examined the merit of different laboratory practicals for the group as a whole through our qualitative data.

RESULTS

Correlation exists between student performance irrespective of assessment type and discipline

Individual student performance data (percentage marks) for each assessment type – written essay paper, EOM MCQ, CAL CBA, and wet practicals CBA was acquired and analyzed. Regression analysis showed significant correlation between student written essay examination scores and the EOM MCQ scores for each individual discipline (biochemistry: $r=0.547$, chemistry: $r=0.540$, physiology: $r=0.417$, and medicine: $r=0.538$) (Figure 1a). The high r values indicate a high degree of correlation and the $p<0.001$ for all disciplines examined indicate very high statistical significance. On further analysis we also investigated if there was correlation between student performance on CAL CBA and wet practical CBA scores. Once again we observed a correlation between both assessments in each of the disciplines analyzed (biochemistry: $r=0.416$, chemistry: $r=0.326$, physiology: $r=0.590$, and medicine: $r=0.646$) (Figure 1b). Thus, our correlation results suggest that students, irrespective of discipline, who performed well in their EOM MCQ were also likely to do well in their written essay paper. Similarly, students who performed well in the CAL practical were also likely to perform strongly in the wet practicals. Conversely, students who performed poorly in one assessment type were also likely to perform poorly in another.

Written essay results versus EOM MCQ results

Mean annual student written examination results were compiled per discipline from AY06/07 to AY13/14 for both the written examination and the EOM MCQ (data not shown). Mean written and MCQ scores per discipline for the 8-year period are outlined in Table 1a. It is immediately obvious that the mean written essay scores for all disciplines are significantly ($*p<0.01$) lower than their respective mean EOM MCQ scores. In addition, the physiology student cohort stand out as demonstrating significantly ($*p<0.01$) lower mean scores in both assessment types over the 8-year period analyzed compared to the three other disciplines (Table 1a). In fact, the physiology cohort demonstrated a statistically lower ($p<0.01$) mean score in seven out of the 8 years analyzed for both assessment types (data not shown).

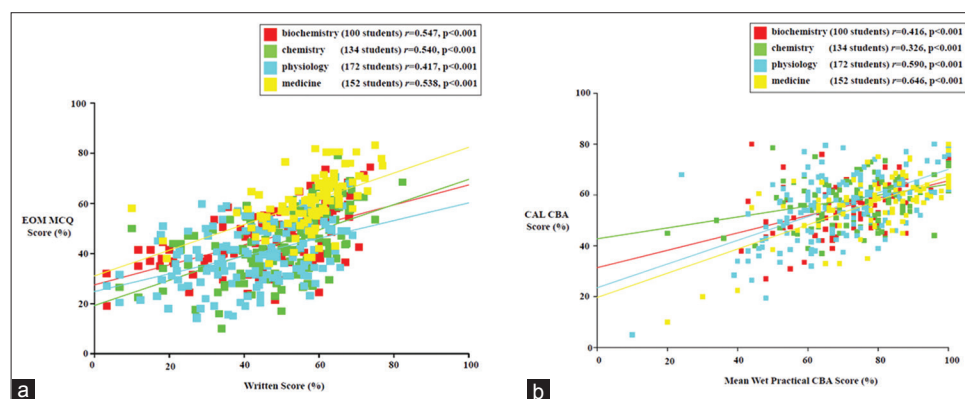


Figure 1: Scatterplots of student performance a discipline in pharmacology from academic year (AY) 06/07 to AY13/14. There were 558 students in total. (a) Scatterplot of written essay individual student scores versus end of module multiple choice question scores and (b) individual student mean wet practical computer based assessment (CBA) scores versus computer-assisted learning CBA scores. Pearson's correlation coefficient (r value) was estimated using the Pearson's product-moment method.

Table 1a: Mean scores (\pm SE) of biochemistry, chemistry, physiology and medicine students in the end of module assessments.

Groups	Mean WR score (%)	Mean MCQ score (%)
Biochemistry	48.16 \pm 1.79*	56.91 \pm 1.30
Chemistry	46.22 \pm 1.34*	53.62 \pm 1.25
Physiology	39.14 \pm 1.19*#	43.27 \pm 1.00#
Medicine	57.33 \pm 1.08*^	60.49 \pm 1.03^

A student's t-test revealed that mean WR examination scores in all disciplines were significantly (* p <0.01) lower than mean MCQ scores. In addition, the physiology student cohort achieved significantly (* p <0.01) lower scores in both assessment types compared to all other disciplines. In contrast the medicine student cohort achieved significantly (* p <0.01) higher scores in both assessment types compared to all other disciplines. MCQ: Multiple choice question, WR: Written essay examination, SE: Standard error

In addition, the range of physiology student scores over the 8-year period was significantly lower than the ranges of all other disciplines in both the written essay assessment and the EOM MCQ (Table 1b). This is in striking contrast to the medical student cohort who displayed significantly higher (^ p <0.01) mean written essay and EOM MCQ student scores (Table 1a) and ranges (Table 1b) compared to all other disciplines.

CAL CBA results versus wet practical CBA results

Interestingly, in contrast to the student marks obtained in the final written essay and EOM MCQ examination a different picture was evident in the CBA analysis. The first observation is that student mean scores across all student disciplines were significantly higher (* p <0.01) in the CBA MCQs (Figure 2) compared to the written essay and EOM MCQ examinations (Table 1a). Importantly and in contrast to the other methods of assessment this included the physiology

Table 1b: Mean scores (\pm SE) and range of scores (\pm SE) of biochemistry, chemistry, physiology and medicine students in the end of module assessments.

Groups	Range of WR score (%)	Range of MCQ score (%)
Biochemistry	30.99 \pm 2.56 to 57.59 \pm 3.54	38.13 \pm 4.61 to 57.60 \pm 2.63
Chemistry	30.13 \pm 5.92 to 60.51 \pm 1.75	38.00 \pm 6.18 to 59.64 \pm 2.27
Physiology	24.98 \pm 3.57 to 48.44 \pm 1.63#	32.98 \pm 3.18 to 51.43 \pm 5.33#
Medicine	43.18 \pm 5.72 to 62.26 \pm 1.47^	52.18 \pm 3.01 to 63.67 \pm 2.31^

The physiology cohort demonstrated a significant (# p <0.01) decrease in both low and high ranges compared to all other disciplines. In contrast the medicine cohort demonstrated a significant increase (^ p <0.01). MCQ: Multiple choice question, WR: Written essay examination, SE: Standard error

student group. On closer analysis, it was evident that all students (except the medicine cohort) performed stronger in their on-line CBA MCQ related to the more hands-on wet practicals compared to the CAL practical (Figure 2). Our findings are in agreement with others where significant variation in student performances between CAL and wet practicals has previously been reported albeit within the same student discipline.^{17,24}

Student responses to CAL versus wet practicals and CBA MCQs

In general, a significant number of students responded to the EOM questionnaire with a mean of 72.3 \pm 16% students completing it annually. Despite the fact that student performances in the CAL CBA were lower than in the wet practicals CBA (except the medicine cohort) (Figure 2), a significant proportion of the student group "strongly agreed"

and “agreed” that both the CAL and the wet laboratory practicals aided student learning (Figure 3). Interestingly over the 8-year period there was no distinguishable difference in student opinions as to the usefulness of the CAL and wet practicals in aiding their overall learning in

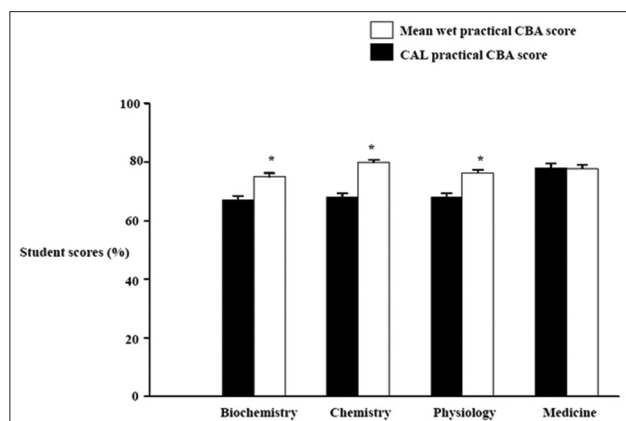


Figure 2: Mean score SE of biochemistry, chemistry, physiology and medicine students in computer based assessment (CBA) multiple choice questions (MCQs) over 8 years from academic year (AY) 06/07 to AY13/14. The CBA MCQs focused on (two) wet practicals and a computer assisted learning (CAL) practical as well as material covered in the preceding four lectures for each practical. Significant (* $p<0.01$) changes in the CAL CBA MCQ scores compared to the mean wet practical CBA MCQ scores.

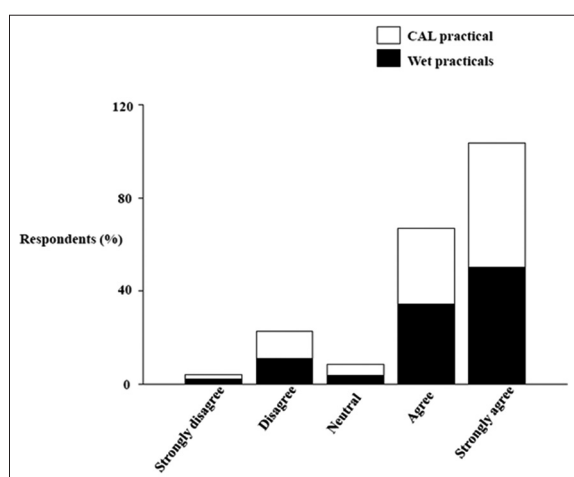


Figure 3: Practicals aided student learning? End of module questionnaires were completed anonymously by students on-line in their own time. Students were asked to give their opinion on whether computer assisted learning (CAL) and wet practicals aided their learning by answering: strongly disagree, disagree, neutral, agree or strongly agree. Percentage mean respondents over the 8-year period (academic year [AY]06/07 to AY13/14) are shown per practical type (black: wet practicals, white: CAL practical). No significant difference was noted between wet and dry practicals for each of the five answers.

pharmacology (Figure 3). Our qualitative data provided a rich diversity of student spontaneous comments on the practical types. Both positive and negative attributes were assigned by students to both wet (Table 2a) and CAL practicals (Table 2b). While student feedback preferences of classical hands-on laboratory practicals versus CAL run practicals is largely mixed which is agreement with previous work by others,^{25,26} it was clear, that there was an apparent student bias toward the utility of wet practicals in aiding student learning (Table 2c, Figure 4). Finally, there was an overwhelming positive student response to the CBA MCQs in terms of aiding students' revision of the module in general as well as their overall learning and understanding of pharmacological topics covered both in the practicals and the associated didactic lectures (Table 2d, Figure 4).

Student Central Administration Office (CAO) entry points, the 2nd year marks and their discipline choice

In an attempt to ascertain why the physiology cohort in particular performed poorly relative to the other disciplines

Table 2a: End of module questionnaires were completed anonymously by students on-line in their own time. The most frequently identified positive and negative aspects of wet practicals.

Phrases from the questionnaire identifying positive attributes of wet practicals
Building practical experiences and skills
Data handling using real raw data
Discovery-based and exploratory
Phrases from the questionnaire identifying negative attributes of wet practicals
Limited scope to undo errors
Waiting period for availability of equipment
Lengthy incubation periods

CAL: Computer-assisted learning

Table 2b: End of module questionnaires were completed anonymously by students on-line in their own time. The most frequently identified positive and negative aspects of CAL practicals.

Phrases from the questionnaire identifying positive attributes of the CAL practical
Good for methodology training
Errors can be corrected in a timely fashion
Continuous availability of the CAL program for revision
Phrases from the questionnaire identifying negative attributes of the CAL practical
No real hands-on practical experience
CAL practicals are easily forgotten
Variation in experimental outcomes is lost

CAL: Computer-assisted learning

Table 2c: End of module questionnaires were completed anonymously by students on-line in their own time. Student comments on both wet and CAL laboratory practicals.

Wet practicals
I preferred the wet practicals over the computer practical. I learned more when performing the task myself
I thought the wet practicals were great, very hands-on
The computer practical was of little use. A wet practical or a tutorial on the material would have been more useful
CAL practicals
The CAL practical did not stimulate my interest or enhance my understanding like the wet practicals
I think the wet practicals are unnecessary if there is a CAL available to simulate the same work
The wet practicals took too long to complete, would have preferred the same experiment taught in a CAL

CAL: Computer-assisted learning

Table 2d: End of module questionnaires were completed anonymously by students on-line in their own time. Specific student comments on practical CBA MCQs.

Practical CBA MCQs
The MCQs were challenging and made me think
The practicals were well-aligned with the associated lectures and the MCQs helped me structure the material
The MCQs guided my learning
The MCQs helped to focus my learning and made the module easier to understand
The computer MCQs aided my revision and understanding of the module
The breakdown of the material with the use of MCQs helped my learning and understanding

CBA: Computer-based assessment, MCQs: Multiple choice question

we looked at CAO entry points to the third level for all students in the past 8 years. We firstly investigated whether or not there was a correlation between students' CAO points (for entry into the Biological and Chemical Science course (CK402) in year 1 in University College Cork [UCC]) and their eventual choice of scientific discipline in year 3 of their scientific studies. Interestingly we discovered no statistical difference in mean students' CAO entry points (over the 8-year period) and their eventual discipline choice 3 years later (Figure 5a). Of note the medical students require significantly higher CAO points for entry into medicine (Figure 5a). Thus, the choice of scientific discipline in year 3 did not relate to initial CAO entry points. However, when we looked further at students' cumulative marks at the end of the 2nd year science we observed that on average science students ending up with physiology as

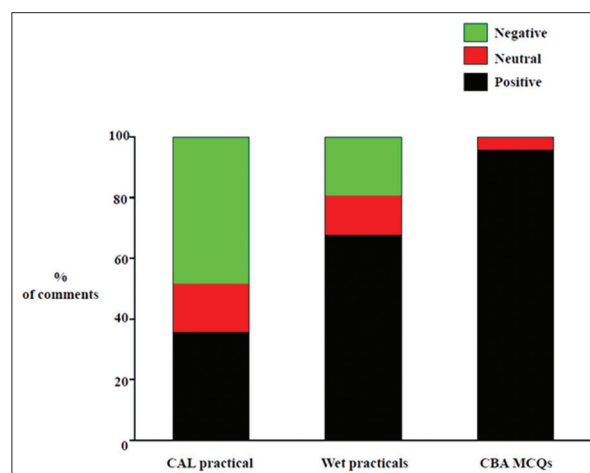


Figure 4: Mean occurrences of positive, negative and neutral feedback from students in the end of module questionnaire from academic year (AY) 06/07 to AY13/14. Students were asked to comment on how computer assisted learning and wet practicals as well as computer based assignment multiple choice questions aided student learning in the end of module questionnaire.

their discipline speciality had statistically lower marks than all other students who specialised in the disciplines of biochemistry or chemistry (Figure 5b). Thus, it would appear that academically weaker students were being funnelled into the discipline of physiology.

DISCUSSION

Examinations have been used as a means of assessing students since medieval times²⁷ and by the Chinese from as early as the Han period (206BC-23AD). In recent times, there has been increased recognition of the need for diverse assessments that are appropriate to the purposes for which the assessment is being used.^{28,29} However, in the discipline of pharmacology assessment at present is mainly by theory writing and *viva voce*. Such methods, however, may not always stimulate students or test higher order thinking.

In our retrospective 8-year study, we examined the impact that assessment type, written essay, EOM MCQ, and CBA associated MCQs, has on multidisciplinary student scores in pharmacology. An important finding of our study is that there was a statistically significant overall correlation between student performance in written essay and MCQ scores in addition to CAL CBA and wet practical CBA scores. Thus, a strong student is more likely to achieve high scores in pharmacology irrespective of assessment type and irrespective of discipline. The same holds true for a weaker student. Whilst our findings are somewhat in agreement with other groups, previous comparative studies analyzed student assessment scores within a single discipline.^{30,31} Our unique comparative findings relate to assessments utilizing diverse multidisciplinary student groups within the one pharmacology class.

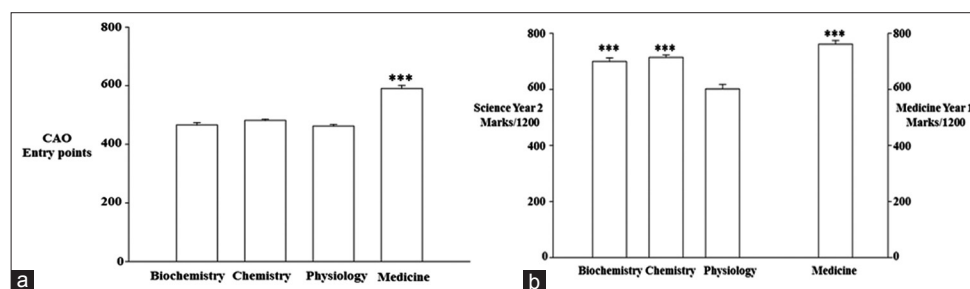


Figure 5: Mean Central Administration Office (CAO) entry points and 2nd year biological and chemical science marks from academic year (AY) 06/07 to AY13/14. (a) CAO entry points, which are third level entry points for students (obtained from their final secondary school examination), taking biochemistry, chemistry and physiology in year 3 and medicine in year 2 of their studies in University College Cork. There was no statistical difference in student CAO entry points according to scientific discipline in year 3 while students taking medicine had significantly ($*p<0.001$) higher CAO points compared to all students taking science. (b) Second year science students' marks and 1st year medicine students' marks according to their discipline in year 2 and 2, respectively, enrolled in module PT3005. The physiology students had significantly ($***p<0.001$) lower mean cumulative 2nd year marks compared to all other science and medicine disciplines.**

We also observed that all students, irrespective of discipline, obtained lower scores in the written essay assessment together with a clear demarcation in multidisciplinary scores. A similar observation of low written scores when compared to other methods of assessment has previously been observed by others.³⁰ These results are not surprising as the written assessment is a sensitive test requiring students not only to recall facts but also to utilize higher order cognitive skills.²⁰ However, students often adopt surface rather than deep approaches to learning³² which can lead to early loss of knowledge in time for the next exam on a different subject. In addition, written essay assessment requires a structured written answer.³³ This skill set may not be honed by all students either through lack of experience or lack of appropriate instruction. Our findings with the MCQ methods of assessment offered some interesting dichotomies. In contrast to the written essay assessment, our use of MCQs in different guises can offer a more sophisticated method of student assessment. In the past, concerns have been voiced that MCQs tend to measure factual recall and recognition of isolated facts.¹² If carefully constructed, however, MCQs (especially single-best answer type) may also test higher-order thinking skills.^{34,35} Higher scores were observed in the EOM MCQ compared to the written essay scores but were strikingly lower when compared with CBA MCQs for all disciplines examined. These differences may be multi-factorial based on assessment type and their associated limitations. The CBA MCQs were not timed which afforded all students time to reflect on the question in a relatively relaxed fashion. In addition, CBA MCQs are open book exams lending themselves to cooperative learning as opposed to individualistic learning which aids student learning and understanding.^{36,37} Furthermore, the CBA MCQs examined a truncated portion of the module as opposed to the entire module. Finally, the higher CBA MCQ scores associated with wet practicals versus the CAL practical may reflect

increased student learning afforded by the hands on team approach in the wet practicals.

A surprising observation from our study is that the student mean grades of the physiology cohort were strikingly lower than all other student disciplines. In general, this was unexpected given the natural synergy between the discipline of pharmacology and that of physiology.³⁸ Pharmacology is taught by underlining the physiological processes that are modified by drugs and thus knowledge of physiology should provide a distinct advantage for student learning in the discipline of pharmacology. Interestingly our findings with the physiology student cohort are not unique to this particular module and have been observed in other pharmacology modules within UCC (unpublished observations). We can rule out certain factors in an attempt to explain why physiology students have performed significantly poorly. These include exam study time, timetabling of continuous assessments across disciplines as well as the compulsory versus optional nature of module PT3005 which was similar for all students (data not shown). We have also gathered data outlining the fact that CAO entry points do not reflect student discipline choice in science in year 3 of their studies. However, what we have observed is that on average there are more science students with lower marks following year 2 of their studies ending up with physiology as their major discipline. This may be somewhat governed by the availability of places in other science disciplines (taking students with higher marks) as well as completion of pre- as well as co-requisite modules pertinent to that discipline. Our findings highlight the fact that on average the physiology student cohort (taking module PT3005) are academically weaker than students from other disciplines in the class suggesting these students are being disadvantaged by being in a multidisciplinary learning environment. Thus, our study begs the question of whether or not the physiology student cohort should be co-taught pharmacology in general

with other disciplines? If both time and finances were not major constraints in the teaching of pharmacology, then this pertinent question could be readily addressed.

From a research standpoint, we have made some interesting observations from our analysis of multidisciplinary student performances in various assessment types. First, there is strong correlation between student performance in written essay assessments and MCQs. However, the differences in mean scores between the two exam types implies both formats may be necessary with the EOM MCQ assessing quantitative information rapidly and the essay examination permitting students to reflect their individual knowledge and interpretive skills. Importantly the continuous CBA MCQ assessment format not only permits a different mode of assessing student knowledge and understanding but also significantly raises student scores. In addition, we also have a clear picture from our research that not all students in our pharmacology class from different disciplines are learning to the same degree which is particularly relevant when dealing with a difficult subject matter such as pharmacology.

The strengths of our report include the diverse multidisciplinary nature of the class group, the 8-year retrospective time period over which analysis was run, the usage of both quantitative and qualitative methods of student assessment and the high questionnaire response rates from students. However, study limitations cannot be overlooked. Outcome assessment (which merely indicates what results have been achieved and how much of them) as a standalone assessment is not always sufficient to clarify causation and improve the quality of student outcomes.^{39,40} Thus, future analysis with the implementation of other modes of assessment including process, input and authentic assessment may be warranted. In addition, looking at the bigger picture such as modes of instruction is necessary to drive improvements in student outcomes. This recently bore fruit for us when we readdressed our teaching strategies in AY13/14 to incorporate discipline tailored teaching (Barry et al., 2015). Utilizing periodic review sessions where teaching, learning and assessment type was more discipline driven than previous years improved student assessment scores. In addition, our research has a somewhat limited focus, i.e. a single discipline at a single institution. Thus, additional research from other institutions would be helpful in confirming our findings. Finally, our findings now allow for a deeper and timely reflection on our modes of assessment and to look at issues of appropriateness of level. Based on our findings we can now strategically plan and design our assessments to constructively align them to the learning outcomes appropriate to each discipline. Our study indicates that progression away from steady state to intended change may help bring about significant improvement in classroom outcomes for all disciplines.

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