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Altering Testing Styles in Biology Courses to Emphasize the Application of Course Content

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As I sat down to write my first biochemistry midterm, I anxiously scrawled out my name on the Scantron sheet. We were reminded for the umpteenth time to write with a number 2 pencil and then our start time finally arrived. I still remember the first question, what is the nucleotide sequence targeted by the EcoRI restriction enzyme? My heart sank.

I had not thought it prudent to dedicate space in my grey matter to memorize this detail. To me, it did not seem like a detail worth testing. Why would I have to memorize these six little letters, when I could look up the answer within seconds? Is it not more important to know that these target sequences can be used to isolate DNA fragments? While this question caught me by surprise, I only had myself to blame because this type of question is quite common.

There is a common perception among McMaster students that courses that fall under the biology umbrella are notorious for asking very fact oriented questions while underemphasizing what those facts may actually be used for. I have heard the exams be likened to a bland game of Jeopardy. Both require you to answer questions about esoteric topics, but little critical thinking is actually necessary. Notably these opinions are not just the product of disgruntled imaginations, nor are they isolated to McMaster. A study surveying 77 introductory biology courses across the U.S. revealed that many examination questions targeted lower cognitive levels, or in other words, the factual based questions that I previously mentioned[1].

In my experience, there are two types of questions that make up an exam in biology. The first is the factual type. These questions test your knowledge about the details of the system and as long as you have memorized the textbook, you should know the answer. An example of this could be "what neurotransmitter is used in the sympathetic nervous system?" These questions are straightforward and do not require much critical thinking. The other type of question requires students to apply their knowledge. I feel these questions more effectively test the students understanding of the content because it usually requires students to think about how the pieces of knowledge are interconnected and relate to the whole picture. An example could be: "The sympathetic nervous system in this organism is defective. Describe what factors could be defective and how it would lead to the observed phenotype". These questions usually incorporate multiple aspects about a topic and they motivate the student to think about how they are linked to each other.

Ultimately the goal of learning the class material is not just to be able to recite it on a Scantron sheet, but instead, to be able to synthesize the knowledge and apply it to novel situations to try and make new discoveries. Education should aim to create intellectually self- sufficient adults so that we may make sound and independent judgments about the world around us[2]. It is to the benefit of society as a whole to cultivate higher level thinking skills so that we may find new solutions to present day issues like climate change or diseases like cancer[3].

That is why the factual type questions are not ideal. The emphasis on the recall of material promotes the superficial understanding of knowledge. However, in order to solve more complex problems in the real world, students must be able to think about how what they have learned may be applicable in a new situation[3]. I am not advocating that courses should ignore the underlying facts altogether. Facts must be taught in order for the overarching concepts to have any relevance[4]. However, I do believe that testing methods in many biology courses have remained pedantic by putting such a large focus on the details.

One method in moving away from the fact-focused style of testing is to decrease or remove multiple choice questions from exams. These questions are pervasive in higher education institutions, and from my experience McMaster is not an exception. Indeed, a 2014 review on the topic of assessment discussing trends and opportunities highlighted this issue[5]. Multiple choice questions are effective in having students discern scientific truths, but they lack the ability to promote critical thinking[6]. Instead there should be an increase in the proportion of written answer questions where the students are presented with a problem and they must propose a solution. The open-ended nature to these questions is more effective in having the student showcase their knowledge in context and it encourages the student to think about how what they have learned applies to new situations[6].

While writing multiple choice questions capable of targeting higher level thinking skills is another viable solution, this method may not yield the most

fruitful results. Designing higher level multiple choice questions is often challenging and most faculty have not received proper training for this task[7]. Furthermore, given that the majority of multiple choice questions currently target lower level thinking skills, students now associate multiple choice questions with memorization and their study habits reflect this perception. A study comparing the study habits of students tested with only multiple choice questions and students who received written answer in addition to multiple choice questions showed that students receiving both types of test questions more frequently used cognitively active study habits. Even when explicitly told that the multiple choice questions were designed to test higher level thinking skills, students expecting only multiple choice questions still used cognitively active study habits less frequently than the students in the other cohort[8].

That is why I believe that there should be a shift to increase the proportion of application questions to reflect a more holistic approach to biology. This change can help create the next generation of scientists to further humanity's quest for knowledge.

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