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TAKEAWAYS FROM TEACHING THROUGH A PANDEMIC

Utilizing discussion boards for test questions: opportunities for students' mathematical creativity and uniqueness

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ABSTRACT

Taking the challenges presented by shifting to online instruction mid-semester due to the Covid-19 global pandemic, I tried to utilize prompts on discussion boards as test questions. The prompts for these questions were to create a triple integral satisfying certain conditions, and when a person posted their integral, no one else could use the same function or bounds. What occurred was a dream to me as an educator – I got to see students being creative, collaborative, and thoughtful, while I enjoyed grading and seeing their uniqueness shine. In this article, I detail the integral prompt and another recent prompt for vectors that led to a merger between my teaching beliefs and actions. I also share about the multiple benefits for instructors, including seeing mathematically clever solutions, and students, including reducing test anxiety and reverse-engineering mathematics problems.

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Incubation; creativity; discussion boards; calculus

1. Introduction

For years, I have been advocating for incubation, or taking a break after a hard problem-solving session, in tertiary classrooms (Savić, 2015, 2016). This is part of my (and our research group's) devotion to fostering mathematical creativity in every classroom (El Turkey et al., 2018; Omar et al., 2019; Tang et al., 2020). A challenge to incubation is that it runs counter to timed tests. Although small amounts of stress may yield some creative ideas, tests are equivalent to anxiety-inducing events for most students (Boaler, 2014). I also walked around my class to keep students from cheating or copying from one another, which possibly contributed to that test anxiety. However, working together was one of my main goals for every class I teach, which runs counter to watching them for cheating. Why can't collaboration be possible while also emphasizing individuality? Finally, tests traditionally were about the answer, and trying to compute that answer as fast as one can (Stipek et al., 2001). This is the furthest possible from incubation and can lead to beliefs about oneself as not being fast (and hence 'math smart') and about the field as strictly focused on products and fast processes.

I had all these beliefs about tests swimming in my head for a long time, yet I kept introducing traditional tests and quizzes in my classes. In the spring semester of 2020,

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COVID-19 shifted our instruction from in-class to online and lined up with my second test for the semester. It was for this test that I tried a technique that will continue for a long time – I posted a prompt on a discussion board (or forum) and laid out requirements for the students' responses, including that their responses had to be unique to each other. This caused a major shift in my approach to tests.

2. The first attempt at discussion-board problem posing

The first test question, from my multivariable calculus course, was as follows:

Create a triple integral in Cartesian coordinates (x, y, z) so that

1) there is a mixed term in the function $f(x, y, z)$ (i.e. you cannot have a function like $f(x, y, z) = x^2 + y^3$ because the x and y terms are separated),
2) that one of the bounds of the 3D region has to depend on the other two (i.e. you cannot have all bounds being numbers),
3) the integral equals 217, and
4) each of your integrals has to be unique to one another. Once an integral is posted, then that function and bounds cannot be used again.

Please post the integral on the discussion board using the 'Insert Math Equation' button, attach a file of your work proving that the integral equals 217, and drawing/demonstrating what your bounds are. Good luck and enjoy!

They were given 48 h to concoct a function and bounds, prove that their integral equalled 217 with all required work, and create a drawing that showed what their bounds may look like. Although most calculus courses offer only linear, straight-forward approaches to the content, the kind of reverse-engineering done in this test can be an important skill in mathematics and beyond (Beghetto, 2017). I had not seen it done anywhere in calculus, so I was not knowledgeable about what the results would be. What happened amazed me and the 34 students in the class as well.

Students approached the prompt with one of two different strategies. The *Factor* approach was to calculate a random function's integral and then multiply by a factor that made it 217 (in full disclosure, I would have done it this way, but it was not the most popular approach). The *Bound* approach was to leave one bound variable and calculate the final bound necessary to have 217. I saw students post their integral and work, and others could see what had been done, but I knew that even seeing the approaches is not enough to solve and create a different function. I could tell they also relied on each other for assistance, because when a post came in with the *Bound* approach, there were many others who used this same approach. I also promoted that they could submit all their scratchwork so that I could assign value to their process instead of only the final product. It was their final products that gave me a starting point to see what they were doing in their process and allowed for the grading to be more for feedback than for points.

It still feels odd to say this because of how time-consuming and frustrating grading has been for me in the past, but I really enjoyed grading the posts. I saw the multivariable calculus concepts that I was testing them on (including triple integration and three-dimensional boundaries), but I also saw how mathematically clever and creative students could be. Whether they were motivated by each other or by efficiency – some chose 0 as one of the bounds, while others chose the bound that depended on the other bounds in a way to cancel out some of the original function $f(x, y, z)$. There were still those that did not display the full knowledge of triple integrals, but they did approach the problem and tried their best to solve their own integral.

I assessed the problem using a 0–4 scale, where 0 was no attempt, 1 was any attempt, 2 was an attempt that show some understanding of the process, 3 was an attempt that had one of two parts correct (or almost correct): the calculation of the triple integral or the diagram of the bounds, and 4 was fully correct. I also graded some with a 3.5 since many aspects were approached correctly, but there was one major flaw in their problem to begin with. For example, a student had a bound from $z = 0$ to $z = 7$, but had a function $\frac{x^2y^2}{z^2}$ that they were integrating. I also gave ample feedback as to why they received the grade they did. I continued this discussion-board procedure, including many of the same requirements, in that same test with cylindrical and spherical coordinates and asked them to write a reflection on the processes of all three. This was the prompt:

> Write one page describing the ways you approached these last three Test 2 discussion questions. In particular, how did you think of your functions and bounds? What was common and what had to be different for each? How did you visualize the bounds?

Students wrote about picking bounds that would help them minimize error and be efficient, but also that the cylindrical and spherical coordinates were different than Cartesian because the angles are bounded. One student explicitly mentioned that they had difficulty and switched bounds, which is another piece of evidence that the longer time for finishing the question allowed for more freedom to learn from difficulties. All four parts were worth 4 points, and I also had a true/false exam in class for the final 4 points, thus totalling 20% of their final grade.

3. Benefits of the discussion-board problem posing

It was incredible to have students create and solve their own problems, especially for such a high-stakes situation. There were so many positives that I will continue the practice in every class. First, I got a chance to allow incubation in my classroom. Giving the students 48 h allowed them to further think about what and how they would approach the problem. In a more recent class, I extended the time to as much as seven days for them to attempt, reflect, and try as many times as they like. Second, the format allows them to use any resource that they would like. It is quite difficult to find a specific problem online that satisfies my requirements, so I can allow them to use anything, including one another's discussion posts, as a resource. Although there are restrictions – students cannot write or copy the post for one another – they are now learning from each other, so there is a sense of collaboration while allowing for individuality. I do realize that students could use computers or websites that can calculate these integrals, but I consider that a resource that the students could leverage and learn from. If I am interested in their process and keep reiterating that I appreciate their thinking and processes, I think that they will be more honest and try to do these processes on their own. This is echoed in Bretag et al. (2019), where the authors stated that students' cheating was 'primarily influenced by dissatisfaction with the teaching and learning environment,' (p. 1848) and offer to counter this with 'supporting students in learning to navigate … a highly connected and networked world, in which sharing and collaboration are an increasing part of professional practice' (p. 1850).

Third, it promotes a holistic view of problem solving. They are the ones that create and solve the problem, and the math education literature on problem posing has stated benefits, such as increased motivation, that are long-lasting (Hošpesová & Tichá, 2015; Silver, 1997). Many students see solving problems as a linear process, so showing 'behind the curtain' allows them to look at problems differently and perhaps dissect what is going on in other math problems. Fourth, it is *their* problem and solution, and I emphasize this because ownership and agency in mathematics can be crucial for developing students' mathematical identities. If they've created this problem, what else can they create mathematically?

There are also benefits for the instructor. The requirements that I posed are not too lengthy, so I had the benefit of saving time creating a test that I believe will show their knowledge and problem solving for the course. As I stated before, the grading was exciting because I got to see clever and creative mathematical moves, something that I do not normally get to see in a traditional test. I do want to say that the grading could get a bit lengthier at times because I was looking at a lot of the scratchwork to give pointed feedback. For example, I estimate that it took five hours on 34 students' first question. However, for every question I've assigned, I've gotten momentum that has allowed for quicker grading times, including seeing similar errors or successes. For larger class sizes, I would recommend finding a balance that is right for you of including these items with other types of assessments. I also liked that I was not hovering over them like in a traditional test, and the uniqueness requirement allows me to trust that they are creating something that is their own. Especially in a triple integral situation, a change in bound or function causes a lot to change in the integration itself.

4. The following semester and beyond

With the same approach, I taught calculus of vector-valued functions, parametric, polar, and sequences/series the following semester. One of the prompts of my first test in that class was the following:

Given the vector $3, \sqrt{5}, 1$, create another unique (to your peers) vector (with non-zero components) so that the dot product of the two vectors is 10. Then, find the:

1. Cross of the two vectors
2. Unit vectors of both
3. Angle between the two vectors
4. Projection vector of your vector onto the given vector.
5. Area of the triangle created by the vectors and the subtraction of the vectors.

You do not have to simplify certain things (keep square roots and all the mess that is inside) if some of your calculations get complicated. Finally, I would like you to draw all of these vectors on one 3D axis. Good luck!

After grading the test question, I noticed that everyone had the same vector for their projection vector, even though they had different vectors to satisfy the rest of the prompt. This was parlayed into a group quiz question, where I asked them why this phenomenon occurred. It reinforced even more the underlying importance of the dot product as not just a simple equation but one that can show the information of one vector on another, which is key for the subsequent major theorems towards the end of calculus (e.g. Green's and Stokes's Theorem). This uniqueness discussion-board prompt allowed me to have deeper conversations about key ideas. It can also be used as a reflective tool to demonstrate the theory – students get to see 30 examples of a concept and can think about the main concept instead of the minutiae or calculations.

Students have also praised the approach. It reduces the amount of anxiety caused by high-stakes testing, which can take up a large amount of their working memory. It also allows students who may not have understood either the prompt or the concept to get more understanding through their peers. Since there is uniqueness built-in, they still get a chance to do their own calculations and reflections. They have also expressed pride over what they created. Generating self-efficacy is difficult, so to have students feel like they can control, approach, and create mathematics can be a turning point in their STEM careers (Regier & Savić, 2020).

This approach is not unique to discussion boards or technology. One can set up these prompts and allow students to work with each other in-class or outside. There are advantages to technology that include the uniqueness of students' responses, but there could be other websites beyond the traditional discussion board such as Discord, GroupMe, or Flipgrid. However, I do enjoy that both the prompt and grading are seamless with Canvas (our learning management system). There are also many ways that students are communicating outside of class, so there is a chance that a prompt of uniqueness will be checked by others outside of class.

This pandemic has forced my teaching to push outside-the-box and to truly commit to what I've dedicated my life to researching – creativity. I saw more creativity in my students, got to create opportunities for them to think deeply, and celebrated their ownership of the material. Creating discussion boards that showcase students' uniqueness while demonstrating understanding of content will be in my pedagogical toolbox for the rest of my career.

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