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TEACHING MATHEMATICS AND RELATED COURSES AT UNIVERSITY OF HOUSTON - DOWNTOWN

JEGDIC, KATARINA
DEPARTMENT OF MATHEMATICS AND STATISTICS
UNIVERSITY OF HOUSTON - DOWNTOWN
HOUSTON, TEXAS

Teaching Mathematics and Related Courses at University of Houston – Downtown

Synopsis:

We give some strategies and ideas tested in undergraduate mathematics, statistics, and data science courses, as well as in undergraduate research and related projects, for improving both students' and instructor's engagement, motivation, and achievements. The main principles include creating an environment with traditional lectures involving theory and computational examples and a two-way communication between the instructor and the students. Student participation is crucial for motivating the instructor to deliver clear and concise lectures and to explain the material effectively.

1. Introduction.

Some of the most pressing challenges in STEM education today are concerned with mathematics and mathematics related courses. Those challenges include:

- recruiting students for these courses,
- filling gaps in their previous mathematics education,
- ensuring that students are able to understand the material,
- keeping students motivated,
- ensuring that students are completing the assignments and are staying engaged, and
- that students are learning the material effectively.

Each of these issues is very complex and requires a thorough understanding of the students' background as well as of their goals. Even though many of the students are often just looking forward to score a certain number of points required to pass the course, with some simple strategies instructors could break this negative attitude towards mathematics and even inspire students to aim for higher achievements. Moreover, if students are showing even slight interest and engagement in class, that has a positive impact on the instructor and motivates the instructor to also aim for higher goals.

2. Strategies

Some simple strategies that have proven to be successful are the following.

a) Give a thorough and clear presentation of the theoretical concepts.

While presenting the concepts, it is important to give students details and explain the topics thoroughly using definitions and abstract objects, while keeping focus on the big picture. Even though the mathematics terminology could be intimidated at first, if the instructor shows that both the terminology and the definitions are natural and intuitively make sense, the students will more clearly understand the concept. Graphs and diagrams are helpful, but still precise mathematics definitions are necessary. For example, when explaining the monotonicity of a function in Calculus I, it is important for the instructor to start writing the definition, but to pose and ask the students to complete it. A graph of an increasing/decreasing function helps students visualize this concept and confirms that the definition derived makes sense. If possible, the instructors should not use pre-written slides, but should write the definitions on the board and have a live interaction with their students.

b) Show examples and counterexamples.

When teaching theoretical concepts, it is important to illustrate each part of the definition or theorem and why it is matters. Examples and counterexamples are very effective in understanding the concepts and their relationships with previously studied concepts. For example, when teaching The Intermediate Theorem in Calculus I, it is crucial to illustrate each assumption and show how when any of the assumption fails, the conclusion of the theorem might fail. It is also important to ask students for such examples and counterexamples as it helps them to think about the concept on a higher level.

c) Give some small insights about the historical background of the concept and/or its relevance to the real-world.

It makes students appreciate the concept more if one can place it in the historical context and give some simple background on its development. For example, when teaching derivatives, it seems that the students enjoy hearing that mathematics is a very old subject and that derivatives are relatively recently discovered. They also enjoy learning why there are several different notations for derivatives and who the scientists who contributed to the area are. Sometimes it is also appropriate to mention how certain concept is relevant to some real-world problems. A simple statement such as that continuity is very important in solving equations that describe motion of gas around a moving object is very effective. Short history lesson or a short explanation of why a concept matters in real life always seem very effective and breaks the monotonicity in the class.

d) Prepare a vast number of technical examples for practice.

Once the students are presented with the theoretical concept and some remarks about it, the time is to practice it. A number of examples of the same type and different types must be given for students to master technical skills. After a certain type of an example is solved, it is crucial for a number of similar examples to follow. This builds student confidence that they are actually able to solve the problems. The two-way communication is absolutely necessary and after the instructor poses a problem, the students should be given few minutes to think about it and suggest some ideas for solving it. Even if the idea is wrong, the instructor should pursue it and discover why that wrong idea fails. It is very important for the instructor to write the solution step-by-step in the beginning since many of the students might have large gaps and also might not be comfortable with even basic mathematical operations. Often when finding derivatives of rational functions using the quotient rule, the students will cancel quantities in the numerator and the denominator in a wrong way. It is very beneficial to stress that this a common mistake and to explain to students how this is properly done. Students also very often memorize the formulas from College Algebra and make mistakes because of it. It is very important for the instructor to always review why those formulas are true. One such example involves various formulas involving exponents. Spending few extra minutes and explaining why those formulas work on simple examples goes a very long way. In fact, it is always beneficial to emphasize that mathematics is not about memorizing formulas, but it is about finding ideas and understanding how those ideas could apply in many different concepts. For example, even in College Algebra, it is useful to tell students that we use the idea of "canceling" in so many different contexts and that this canceling often refers to applying a function and its inverse.

e) Inform students that their success depends not only on their instructor, but also on the time they spend studying for the course.

It is very beneficial to repeat to students over and over again that their success ultimately depends on the time and effort they invest in the course. If the students are only coming to class and simply copying down the questions and answers, even if they are participating in solving the problems, it is important to stress that this is not enough. The instructor must emphasize, maybe from his/her own experience, that mathematics seems easy when someone else is solving problems, but the students must try many problems on their own in order to become comfortable with the concept. For example, it is very helpful to state that Calculus I is just a transition course to the upper level mathematics and that it is not hard, but just requires time. It is also useful to tell students that instructor understands that students have other courses and many other obligations, but if they could make some fixed schedule during the week for studying and if they try to stick to that schedule, it might help them in mastering the course. Sometimes it is also useful for instructor to bring his/her own experience and state that they also had difficulties with the material, but they worked very hard to learn it and it paid off. When teaching Calculus I, it is also useful to state that mathematics majors (whether or not there are any in the course) learn these concepts again and in a much more detailed way in some upper level courses such as Analysis. Students need to be encouraged that, for example, Calculus I is a bridge to understanding upper level mathematics and related areas and that one cannot solve complicated real-life problems just using College Algebra.

f) Prepare a large number of homework questions.

For students to effectively gain technical skills, a large number of homework questions is absolutely necessary. Even if technology (such as MyMathLab, WebAssign, etc.) is used, it is important to tell students to write their complete solutions on the paper and not simply look at the screen and try to solve or guess the solutions. It seems very helpful to state that the use of technology is simply just for efficient grading and feedback, while learning mathematics is the same as it was thousands of years ago when there was no technology. It is also important to stress that even though it matters that the final solution is correct, it matters even more that the solution process is correct. This helps students not to focus too much on the technology, but actually they focus on solving the problems and getting the solution process right.

g) The instructor must show passion, interest, and expertise in the subject.

If the instructors are simply just delivering the material, no matter how well of educators they are, if they are not experts in the subject and do not have passion and interest in it, the student learning experience might not go a long way. However, if the instructors show expertise and often point out in simple words how the concepts relate to some very complicated topics, the students will get more engaged and more interested in the material. Especially, if the instructors could point out to some recent discoveries in mathematics that are related to the concept taught, the students will feel that what they are studying is important in real-life. This seems to be much more beneficial and effective than solving some real-life examples from the textbook.

h) Provide students with an interesting extra credit assignment.

Instead of giving students an extra credit assignment that consists of another set of textbook problems they need to solve, instructors should be more creative and incorporate some different ways to boost student interest. In fact, instead of giving the extra credit assignments at the end of the semester when the students already have too many exams, it has proven more beneficial to give students extra credit assignments just when the semester starts. Two examples of such extra credit "assignments" for undergraduate students enrolled in a mathematics or a mathematics related course, regardless of student major, are the following.

- Ask students to attend a meeting of the math student club on campus or to attend a mathematics seminar. Typically, this is a simple way to show that mathematics is much more than a set of textbook pages. If the students attend a meeting of the math club and meet other students interested in mathematics, often their senior peers will have a much more effective way to attract them to mathematics than their instructors. Also, if the students have an opportunity to attend a mathematics presentation, even if they do not understand much, they could see that mathematics is much more than the course they are taking and it often sparks an interest in a few students about what mathematics research is about.
- Ask students to watch a documentary on mathematics or history of mathematics and write a short essay about it. There are many documentaries on mathematics available on youtube that are done for lay people, but in very effective, visual, and interesting ways. For example, there is a documentary with a debate whether mathematics is discovered or invented where a number of mathematics experts give their opinions, in addition to many history lessons on mathematics, its appearance in nature, and its application to modern technologies. The students could be asked to write a 1-page essay on what they think on the topic. It seems that they enjoy watching such documentaries and that they inspire students to think of mathematics in a very different way than to what they were exposed to in high schools.

i) Become a mentor.

The instructor must show interest in students and their education beyond just teaching the concept. It is important to ask students what their majors are and to point out occasionally how some concepts would be used in their future studies. For example, when teaching Calculus I, whether or not there are any data science majors present, it seems effective to mention that one back-bone of data science is actually calculus and that algorithms such as neural networks (since everyone has heard of them regardless of their major) use optimization techniques we study in calculus. It is important to bring those very complicated concepts in relation to concepts studied in the class. Connecting the subject to student majors brings the subject closer to students and they often become more engaged and motivated to study it. In addition, the instructor could stress that mathematics skills are often called quantitative skills, analytical/critical skills, etc., and they are what the employers are looking for. Consequently, such simple talks often result in shaping student opinion of mathematics and the instructor could influence the direction student is taking. Non-mathematics majors could often be motivated to pursue mathematics as their minor and sometimes even motivated to pursue a mathematics related graduate program. In fact, the students often say that their hate/love for mathematics is actually a result of their instructor's input.

3. Conclusion

Even when the instructor has taught the same course many years, teaching a new group of students is a unique experience and one can try with very simple ways to make the best of it. The students usually appreciate small and simple suggestions that are given with a genuine interest in student success. Short talks and comments during the lectures break the monotonicity and boost students' attention and interest. Complaining that students come with gaps in their education and complaining that they are not learning the material will never be productive, and the instructors should take a sincere initiative on how to deal with it. Even if students learn very little in high school and come unprepared to college, the instructor could still make a difference and a positive impact in just one semester. The students need to be respected for what knowledge they bring and should be shown that they still have time to grow and prosper. It takes time and effort from both sides, and both instructors and students need to understand it and have patience. As much as instructors want their students to be engaged in the course, the students also expect from instructors to show genuine engagement, passion, interest, and expertise in the subject. Neither students nor the instructors should be focused on making good grades, but on the actual learning experience. It seems counterproductive to search for some innovative ideas and the best way for the instructors to improve student achievements is to simply think of the ways they learnt the subject and to try to bring their own success to their students.