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Using Student Response Systems for Peer Instruction and Active Learning in the Classroom

Mike MacCallum, PhD
Emeritus Professor of Astronomy
Long Beach City College
Long Beach, California

Contact information:

2810 Faust Avenue
Long Beach, CA 90815
mmaccallum@verizon.net
1 562 787 0999

> *Lecturing is that mysterious process by means of which the contents of the note-book of the professor are transferred through the instrument of the fountain pen to the note-book of the student without passing through the mind of either.* (Miller, 1927)

More recently, research on active learning and the brain conclude that the most effective learning takes place when students are actively engaged in the learning process. (See for example, Mintz, 2015) Moreover, a recent meta-analysis of research found that active learning increases student achievement and reduces the risk of failure in science, technology, engineering, and math (STEM) classes. (Freeman, et al., 2015)

The purpose of this paper is to describe in a practical manner how to flip a classroom, and to engage students in active learning using audience response systems and group projects. The paper will present specific techniques that may be directly adapted to the classroom. The methods include flipping the classroom, a research-based active learning technique using a simple audience response system, a second, group-based active learning technique, and an example of group problem-solving projects. This paper will also discuss different audience response systems and student evaluation/grading options in an active learning environment.

The underlying concept behind this paper is that students do not learn by being exposed to material a single time. Effective learning takes place when students are engaged with the subject and use its concepts multiple times, in a variety of ways, similar to learning a foreign language. Active learning engages both the student and the professor in the process of learning.

1. Flipping the classroom

One of the key ingredients to engaging students in active learning is to “flip” the classroom (see,

for example, Brame 2013). Essentially, in a flipped classroom, students read the lecture materials on their own prior to class and then during class, students engage in activities, similar to what might be assigned for homework. The steps to flipping a classroom are as follows:

A. Post the class lectures online. Typically, those lectures should be posted to the college or university website, but other websites may also be used, such as Google Docs.

B. Optional: To ensure that students read the lecture notes before class, administer a short, 10-question quiz at the start of each class or require students to write a one-page summary of the lecture notes, to include: a summary of the lecture, the most important points, and anything that was unclear or didn't make sense.

C. Do not lecture for the entire class time. Give short (no more than 10 minute) lectures interspersed with conceptual problems and group projects.

Those instructors who are used to lecturing will need to let go, step down from the stage in front of the class and become more of a moderator, facilitator, or maybe a coach. Interacting with students becomes the focus of the classroom.

Materials must be developed for the flipped classroom. These materials can be prepared by the instructor, obtained through academic organizations, or adapted from homework assignments. For example, the Center for Astronomy Education, sponsored by NASA, provides a wealth of classroom materials, conceptual questions, and group projects for use in astronomy classes.

There will be a learning curve. Once a class has been flipped, it will take some time to figure out the proper amount of material that can be covered and the kinds of activities that will work best for each class.

<u>2. A research-based, active learning technique</u>

A. Decide upon an audience response system to use in the classroom. See Appendix A.

B. Prepare or obtain a set of conceptual questions for the subject matter being taught. Put these questions into a PowerPoint or Keynote presentation suitable for the length of the class session. Each question should be multiple choice with the number of choices being dependent on the response system being used.

C. If using clickers or a cell phone response system, use the following steps for each of the questions (Mazur, 2015a,b):

1) Without giving an introduction, display the first conceptual question.
2) Students can input their answers as soon as they are ready to answer.
3) Watch the answers coming in and, after a couple of minutes, encourage the last few students to put in their answers (there will almost always be a couple of stragglers).
4) Once all the answers are in, look at the results. If more than about 80% of the students got the correct answer, display the results to the students and congratulate them. Ask if there

are any questions and then go on to the next question.

5) If less than about 20% of the students got the correct answer, display the results to the students and give a short lecture (no more than ten minutes) about the concept. Ask if there are any questions and then go on to the next question.
6) If between about 20% and 80% of the students got the correct answer, do not display the results. Turn to the students and say the following: "I want you to turn to the students around you and find a student with a different answer than yours. Discuss your answers with each other and try to decide which is the correct one. Remember, you and the student you are talking to may or may not have the right answer." If the number of students who got the answer right is small, you can also provide some clarification at this point.
7) Typically, the classroom will erupt into discussion. Let the discussion go until you can see that the talking is beginning to quiet down. Walk around the classroom and listen in on some of the discussions. Without giving away the answer, you can provide some guidance and encouragement, such as, "Yes, you are on the right track!"
8) Once the discussion slows down, re-poll the students. Typically, the number who have the correct answer will now be 80% or more and you can congratulate the students and ask if there are any questions.
9) If the number of right answers has stayed the same or even gone down, you can do one of two things:
    a) Ask the student if they have a question about the concept that would help them understand it better. Then go back to step 6 and have them talk with their neighbors again.
    b) Give a short lecture on the concept (no more than ten minutes) and move on to the next question.

D. If using a paper or card-based response system, use the following steps for each of the questions (Brissenden and Prather, 2015):

1. Without giving an introduction, display the first conceptual question.
2. Turn your back to the class and slowly read the question and its answers to yourself, thereby giving the students enough time to read the question. Do not read the question out loud.
3. Turn back to the students and ask, "Does anyone need more time?" If anyone says they do need more time, turn back to the question and slowly count to ten. Then call "time".
4. Turn back to the students and ask them to prepare their answers. They will choose their card or fold their paper to display their answer.
5. Count to three and ask the students to show their answers to you, without showing them to the rest of the class.
6. From the front of the classroom, look over the answers to see, generally, how much of the class is displaying the right answer. If more than about 80% of the students got the correct answer, confirm the correct answer and congratulate them. Ask if there are any questions and then go on to the next question.
7. If less than about 20% of the students got the correct answer, give a short lecture (no more than ten minutes) about the concept. Ask if there are any questions and then go on to the next question.

8. If between about 20% and 80% of the students got the correct answer, say the following to the students: “I want you to turn to the students around you and find a student with a different answer than yours. Discuss your answers with each other and try to decide which is the correct one. Remember, you and the student you are talking to may or may not have the right answer.” If the number of students who got the answer right is small, you can also provide some clarification at this point.
9. Typically, the classroom will erupt into discussion. Let the discussion go until you can see that the talking is beginning to die down. Walk around the classroom and listen in on some of the discussions. Without giving away the answer, you can provide some guidance and encouragement, such as, “Yes, you are on the right track!”
10. Once the talking has died down, ask the students to prepare their answers again. Count to three again and ask them to show you their answers. Typically, the number who have the correct answer will now be 80% or more and you can congratulate the students and ask if there are any questions.
11. If the number of right answers has stayed the same or even gone down, you can do one of two things:
    c) Ask the student if they have a question about the concept that would help them understand it better. Then go back to step 5 and have them talk with their neighbors again.
    d) Give a short lecture on the concept (no more than ten minutes) and move on to the next question.

In planning your class sessions, allow about five to ten minutes for each conceptual question. The length of time will depend on how many correct responses you get from the students, how long it takes the class to discuss a question, and how many questions are asked by the students. As can be plainly seen, you must remain flexible with the time and it is best to not try to rush the students in order to get through all of the conceptual questions that were scheduled for that session.

In a long class, anything more than about an hour, don’t try to spend the entire class time doing conceptual questions. Students can become fatigued and begin to lose interest. Keep your eyes open and switch to another activity if you can begin to see that your students are losing focus.

Typically, this activity is not graded, although you may give points for participation.

<u>3. Another active learning technique using audience response systems</u>

A. Decide upon an audience response system to use in the classroom. See Appendix A.

B. Prepare or obtain a set of conceptual questions for the subject matter being taught. Put these questions into a PowerPoint or Keynote presentation suitable for the length of the class. Each question should be multiple choice with the number of choices being dependent on the response system being used.

C. Use the following steps:

1. Count the number of students in class and then have them count off so as to form groups of four or five students. For example, if there are 40 students in class, you could have them count off by tens, forming 10 groups of four students each or count off by eights to form 8 groups of five students each (all the ones, twos, threes, etc. form into groups). It is best to conduct the counting so that couples and cliques of friends are spread out into different groups.
2. Optional: These groups can be made permanent and kept together for the entire class. In that case, have them choose a name for themselves, based on the subject matter of the class. Each time there is a group activity in the class, the same group members will work on the activity together.
3. Give one response device or response card to each group.
4. Display the first conceptual question.
5. Ask the groups to discuss the question amongst themselves, within their group.
6. If using clickers or a cell phone response program, groups can answer as soon as they agree upon an answer. If cards or paper responses are being used, make sure each group has their answer and then count to three and have the groups display their answers all at the same time.
7. Since the discussion has already taken place, display the right answer immediately. Then ask for questions and/or give a short lecture (no more than ten minutes) to clarify the concept being discussed.
8. Optional: Keep track of the right answers by group and at the end of the session, announce which group got the most number of questions right.

Typically, this activity is not graded, although you may give points for participation.

<u>4. Group projects and problems</u>

The use of group projects and activities is another effective active learning method. Here, too, you must find or create group questions or problems that are related to the subject being taught. The best questions or problems are open-ended and require the student to apply the concepts being taught in the class to different, novel situations.

1. Give the question or the problem to the students, either by displaying it on the overhead or passing it out to the class. Give the students a few minutes to think about the question before the discussion begins.

2. Break the class up into groups of four or five students each, as described above or ask the students to form into their groups, if you are using permanent groups that were formed at the beginning of the class.

3. Tell the students to choose a group leader who leads the discussion, a recorder who writes down the group's ideas as they are developed, and a reporter who will report the group's findings to the rest of the class. Those roles should be switched around each time groups work together, so each student gets to participate in each role.

4. Give the students 10 to 15 minutes to discuss the problem. Walk around the room and

listen to the discussions. Answer questions, if needed, and give encouragement, to help the discussion move forward.

5. When the discussion begins to wind down, tell the class that they have one or two more minutes to finish up.

6. Call time and ask each group to report their results to the rest of the class.

7. In group work, there typically is no one right answer, so at the end of the exercise, summarize the reports of the groups and comment on their conclusions.

Because group discussions often have no one right answer, the groups should typically not be graded for their answers, although participation points may be given.

5. Other active learning assignments

Since the purpose of active learning is to get students up out of their seats and engaged with the material being studied, the following assignment may also be given:

A. A paper on a topic appropriate to the subject matter in the class. In this regard, multiple, shorter papers would engage the student in a variety of course topics and be better than a single, longer paper.

B. A field trip to a place (if available) related to the subject matter covered in the class. Students should be asked to produce some kind of proof of the field trip and write a brief summary of the experience.

C. Group presentations on some topic appropriate to the class.

D. Ask the class to look for articles in newspapers and magazines or online that are related to the class and write or give a short report on the article and how it relates to the course.

With these other types of assignments, a grading rubric should be used to ensure that grading is as fair and objective as possible.

6. Grading in the flipped, active learning classroom

In the traditional classroom, students are typically evaluated by tests administered at different times during the class, with a midterm and a final exam at minimum. The flipped, active learning classroom presents us with an opportunity to rethink how we evaluate our students. Consider the following options:

A. Continue to evaluate students in the traditional way with the same tests that have been used for the class in the past.

B. Eliminate all exams and evaluate students based on their participation and engagement in the class.

C. A blend A and B: Give a graded quiz at the beginning of each class session to make sure that the students are reading the lecture notes, give points for attendance and/or class participation, give grades for papers and class presentations, and give points for other active learning assignments, such as field trips and reports on news articles.

There is no one right assessment method. The important thing is to realize that when a classroom is flipped and students are engaged in active learning, we also have a chance to rethink how we evaluate and grade our students.

7. References

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APPENDIX A. Audience response systems

Clickers are excellent response devices that are simple to use and give flexibility in designing questions and monitoring responses. Clickers have unique ID numbers, which can be associated with the individual students in the class. Clicker responses can be used for grading a quiz, for awarding attendance points, and for taking attendance. They can also be used to display responses graphically, showing the number of students who have responded to each of the multiple-choice answers. For a general overview of clickers, see:

http://en.wikipedia.org/wiki/Audience_response

Clickers are rather expensive (US$30 to 40 each), but if an institution as a whole adopts active learning, they can sell clickers at the bookstore and a student need buy only one, which can then be used for all classes that the student takes at the institution.

Two well-known clickers are iClicker and the Turning Technologies Response Card.

https://www1.iclicker.com
https://www.turningtechnologies.com/response-solutions/responsecard-rf?silo=he

There are two cheaper solutions:

1. There are polling programs that use cell phones, although that requires all your students to have a cell phone (which was a problem for me when I was teaching). Here is one example:

http://www.polleverywhere.com/audience-response-system/?ref=PIW0qgbZ&gclid=CNuVrpao-8MCFYZffgodlH8AAw

Another is the eClicker system available through the Apple app store.

https://eclicker.desk.com

2. You can also use a plain sheet of paper divided up into four squares. Each square has a large, bold number (1 through 4) and a different color. In response to a question, students fold the paper and to show their answer. The teacher visually inspects the number of red, green, yellow, and blue responses to see if the students understand the concept being discussed.

APPENDIX B. Sample conceptual questions from the field of astronomy (Prather, 2012)

1. According to Newton's law of gravity, the force of gravity between two objects is given by:

$$F = G\frac{m_1 m_2}{r^2}$$

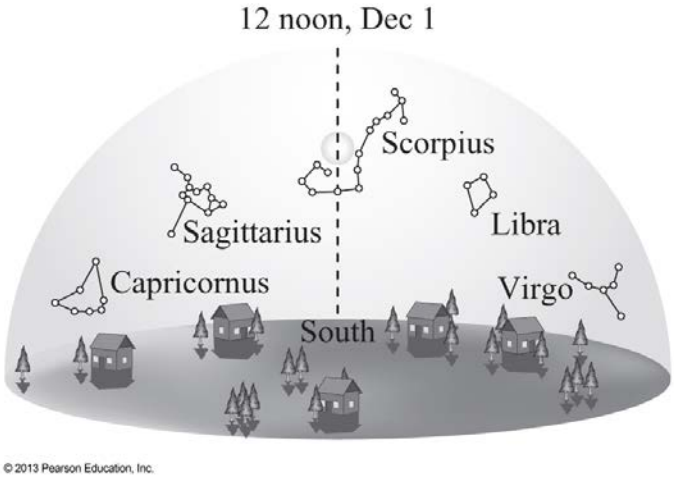
Where F is the force of gravity, G is a constant, m_1 is the mass of the first object, m_2 is the mass of the second object, and r is the distance between them.

Given that Earth is much larger and more massive than the moon, which of the following is true:

A) The force of gravity of the earth on the moon is larger
B) The force of gravity of the moon on the earth is larger
C) The force of gravity of the earth on the moon is the same as the force of gravity of the moon on the earth
D) None of the above are true

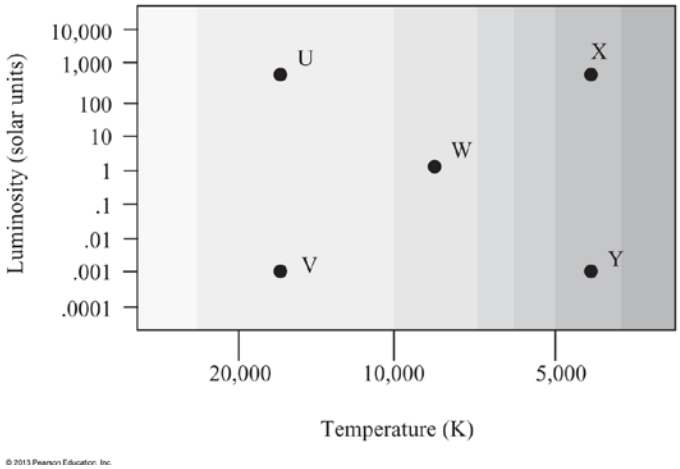
2. At noon on December 1st, in the picture below, the sun appears to be in the constellation Scorpius (if you could see the stars in the middle of the day). Three hours later, at 3:00 PM, where will the sun appear?

A) In Capricornus
B) In Sagittarius
C) In Scorpius
D) In Libra
E) In Virgo
F) You cannot tell from the diagram



3. When plotted on the Hertzsprung–Russell (H–R) diagram, below, stars U and V have the same temperature, but star U is much more luminous (brighter). What can you conclude about the size of star U compared to star V?

A) Star U must be much larger than star V
B) Star V must be much larger than star U
C) Because they are the same temperature, they must be the same size
D) You cannot tell from the diagram which star is larger



APPENDIX C. Sample group discussion topics from the field of astronomy

1. One of the most earth-like planet discovered to date is Kepler 438b, which is about 470 light years away from Earth. You and your group have been selected by the United Nations to prepare a message to send to Kepler 438b. You can send any digital message you want (pictures, audio, movies) and there is no limit on the size of the message. What will your group send and why?

2. In 2005, NASA estimated that it would cost US$105 billion to send astronauts back to the moon. In your group, carefully consider the pros and cons. Should mankind return to the moon? Why or why not?

3. It is 2025 and the lunar shuttle carrying your group has crash-landed on the moon, about 80 km (50 miles) from the lunar outpost you were headed to. You decide to walk to the outpost. Inside the shuttle, you find the following equipment. Rank the items from most to least important to help you in your journey.

Inflatable life raft, oxygen tanks, space blanket, solar-powered, rechargeable light, signal mirror, water, first aid kit, food, magnetic compass, solar-powered radio/transmitter, map of the moon, rope, parachute, space suit repair kit, box of matches.