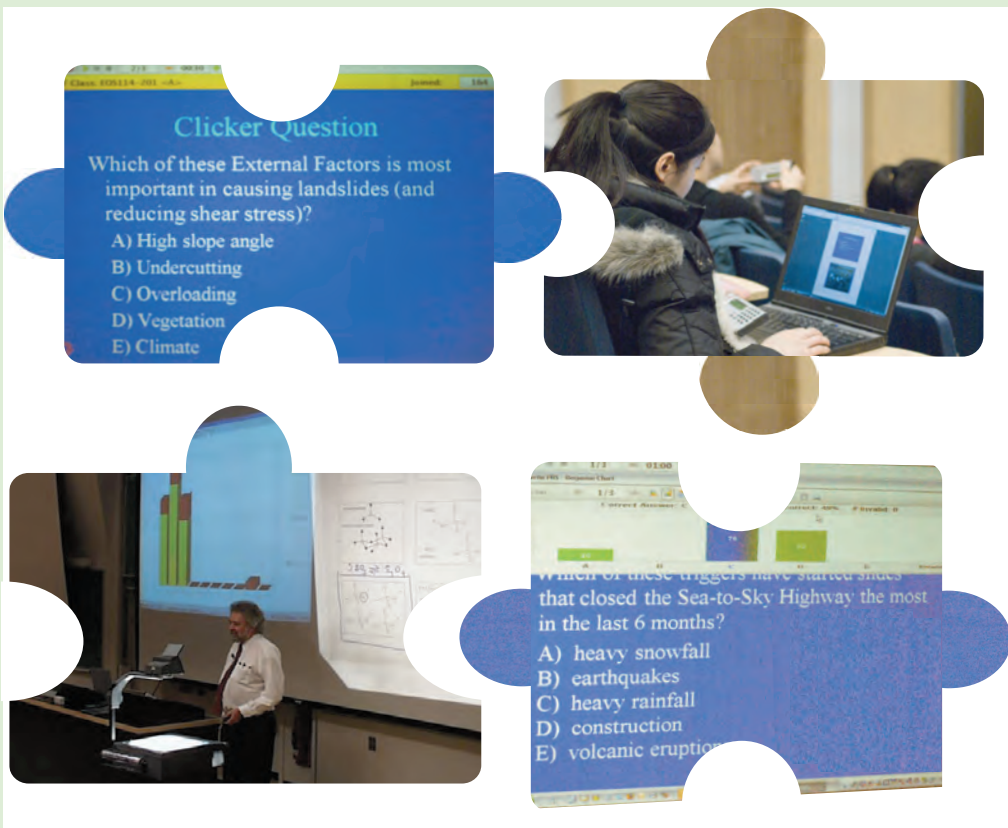


Clicker Resource Guide

An Instructors Guide to the Effective Use of Personal Response Systems (Clickers) in Teaching



Prepared by staff of the CU Science Education Initiative
and the UBC Carl Wieman SEI*

Connecting students in an interactive classroom experience.



Layout and Design: Michael Wong
Cover Design: Stefanie Wudel
Cover Photos and Inside Cover Photos: Zack Lee

TABLE OF CONTENTS

Executive Summary	2
Introduction	3
Using Clickers in the Classroom	6
1. Types of clicker questions	6
2. Recommended approach to using clickers	6
3. Writing effective questions	10
4. Introducing students to the use of clickers	14
5. Logistics	15
6. Coverage of material	16
7. Dealing with unexpected situations	17
Multiple Goals of Using Clickers	19
Frequently Asked Questions about the Use of Clickers and Clicker Questions	20
Appendix	28
References	33

* (Carl Wieman, Katherine Perkins, Sarah Gilbert; Life Sciences CU: Francoise Benay, Sarah Kennedy and Kate Semsar, Jenny Knight, Jia Shi and Michelle Smith; Life Sciences UBC: Tamara Kelly, Jared Taylor, Harald Yurk, and Gulnur Birol; Chemistry CU: Laurie Langdon, Tom Pentecost; Chemistry UBC: Jackie Stewart; Geological Sciences CU: Leilani Arthurs, Andrea Bair, and Jennifer Stempien; Earth and Ocean Sciences UBC: Brett Gilley, Francis Jones, and Ben Kennedy; Physics CU: Stephanie Chasteen; Computer Science UBC: Beth Simon)

EXECUTIVE SUMMARY

- Clickers are not a magic bullet – they are not necessarily useful as an end in themselves. Clickers become useful when you have a clear idea as to what you want to achieve with them, and the questions are designed to improve student engagement, student-student interaction, and instructor-student communication.
- What clickers do provide is a way to rapidly collect an answer to a question from every student; an answer for which they are individually accountable. This allows rapid reliable feedback to both you and the students.
- Used well, clickers can tell you when students are disengaged and/or confused, why this has happened, and can help you to fix the situation.
- The best questions focus on concepts you feel are particularly important and involve challenging ideas with multiple plausible answers that reveal student confusion and generate spirited student discussion.
- A common mistake is to use clicker questions that are too easy. Students value challenging questions more and learn more from them. Students often learn the most from a question that they get wrong.
- For challenging questions, students should be given some time to think about the clicker question on their own, and then discuss with their peers.
- Good clicker questions and discussion result in deeper, more numerous questions from a much wider range of students than in traditional lecture.
- Listening to the student discussions will allow you to much better understand and address student thinking.
- Even though you will sacrifice some coverage of content in class, students will be more engaged and learn much more of what you do cover.
- When clickers are used well, students overwhelmingly support their use and say they help their learning.
- When a significant fraction choose an incorrect answer, it is important to go over why that answer is incorrect and not just give the correct answer.

INTRODUCTION

Why is it that every faculty member who is experienced with using clickers effectively swears by them?

Why are the students in classes using well-implemented clicker questions dramatically more engaged and asking more numerous and deeper questions?

Why do the students in these classes overwhelmingly recommend that clickers should be used in all lecture classes?

This guide was written to help instructors understand the answers to these questions, and to help them use personal response systems (“clickers”) in their classes in the most comfortable and pedagogically effective manner. The authors are involved in the Science Education Initiative at the University of Colorado and the Carl Wieman Science Education Initiative at the University of British Columbia. We have supported many different instructors as they

“This is great fun. My worst day using clickers is about as good as my best day using standard lectures [in the past].”

introduced or refined the use of clickers into their courses, several of us have used clickers extensively in teaching, and we have observed a large number of classes – both those which use clickers and those which do not. Particularly relevant to this guide were our numerous observations of some expert “clicker-based” instructors. We have also carried out a number of studies on clicker use and their impact on students and on student opinions about their use.

The first point about clickers that must be emphasized is that clickers in themselves are not a solution to anything. Like a chalkboard, they can only serve to extend the capabilities of the instructor. Although clickers can be, and unfortunately often are, used primarily to encourage attendance, they are most effective when they are used expressly to facilitate intellectual engagement of the student and communication between student and instructor. When used this way, the amplification of a good instructor’s capabilities can transform a classroom and result in dramatically improved student learning, particularly in large classes. In the words of one instructor known to be an exceptionally good traditional lecturer when half way through his first term of using clickers: *“This is great fun. My worst day using clickers is about as good as my best day using standard lectures [in the past].”*

An experienced insightful instructor when giving a traditional lecture can tell when many of the students are not engaged and can often tell when students do not understand the material. However, it is more difficult to know *why* they are disengaged and/or confused, and how to fix these problems. Clickers, when used well, can provide the *why* and *how to fix* for experienced instructors. For other instructors, in addition to serving those functions, clickers can also help them know much better *when* students are disengaged and confused.

It is essential to recognize that these benefits do not happen automatically when one introduces clickers to the classroom. These desirable outcomes are only achieved when the instructor thinks carefully about his or her instructional goals and how clicker questions and related discussion can help achieve those goals. In the remainder of this document, we will discuss the use of “clicker-questions” and how they can be used in educationally effective ways. These questions are normally multiple choice questions posed to the class, where each student in the class has their own clicker. Students register their answer by pushing the appropriate button, and a computer records their response. A histogram of responses can be shown to the whole class.

It can take some time to tap the full potential of clickers in the classroom. We have commonly seen instructors follow the following progression as they learn to use clickers effectively:

Seeing [the response from clickers] is often an “aha” moment for the instructor. They realize how they might use clicker questions in a new way to better promote student thinking and learning...Students recognize that they must come to class prepared and must keep up with material throughout the semester, as they must analyze and respond to questions on a daily basis.

Stage 1) Asking simple, primarily factual, questions as a starting point. These questions are often simple quizzes on material just covered in lecture, or questions derived from the textbook or textbook instructor's guide. Little discussion amongst students about the questions is encouraged or needed, and the great majority (>80%) of the students get the question correct. There is little follow up discussion to the question by the instructor. This type of question often appears to be driven by instructor's concern that asking more difficult questions would make students feel uncomfortable at missing the answer. The primary impact of the clickers on lecture is improving attendance (assuming students get points if they answer the questions). On our surveys, students indicate they see much less value to this type of use than clickers being used as in Stages 2 or 3 below.

We have seen some faculty members who are new to clickers suddenly switch from the simple usage of clickers in Stage 1 to the more effective approach in Stages 2 or 3 after the following experience. Stimulated by unexpectedly poor performance on an exam question or just by accident, the instructor will create a question that is more challenging. This question creates a large split in responses that is followed by a burst of discussion among the students as to which answer is correct and why. Seeing such a response is often an "aha" moment for the instructor. They realize how they might use clicker questions in a new way to better promote student thinking and learning. They then move to the next stage of clicker question use.

Stage 2) Asking more challenging conceptual questions, or questions where the answer is not obvious and critical points could be argued. There is a substantial spread in student responses and significant student-student discussion of the question is encouraged, with follow up discussion by the instructor. There are occasional changes in the planned lecture to address student difficulties that are revealed by the clicker question or in response to student questions generated in discussion.

Stage 3) Lecture is structured around a set of challenging clicker questions that largely embody the material students are to learn. Students are required to prepare for class by reading or carrying out assignments ahead of time, and little class time is spent in providing information to students that is accessible in the textbook or online notes. Students are organized into 3-4 person discussion groups so that all students must discuss the questions, and student reasoning for their answer choices are elicited and analyzed following the question. A significant portion of the class time is devoted to discussion of students' thinking and questions that are revealed and raised during this process. Under the best of circumstances, clicker questions are designed so that student questions actually introduce the next intended topic (and may even constitute the next clicker question posed to the class). Students recognize that they must come to class prepared and must keep up with material throughout the semester, as they must analyze and respond to questions on a daily basis.

USING CLICKERS IN THE CLASSROOM

1. TYPES OF CLICKER QUESTIONS

Clicker questions can serve many purposes – below are some common uses:

- 1) Quiz on the reading assigned in preparation for the class
- 2) Test recall of lecture point
- 3) Do a calculation or choose next step in a complex calculation
- 4) Survey students to determine background or opinions
- 5) **Elicit/reveal pre-existing thinking**
- 6) **Test conceptual understanding**
- 7) **Apply ideas in new context/explore implications**
- 8) **Predict results of lecture demo, experiment, or simulation, video, etc.**
- 9) **Draw on knowledge from everyday life**
- 10) **Relate different representations (graphical, mathematical, ...)**

While each mode can be useful in the right circumstances, those in **bold** above are the uses that we have seen the largest direct impact on learning and the uses that students report they find of most value. Not surprisingly, these reflect the deepest mastery of a subject and hence have been shown to be the most challenging for students to learn. We recommend that the majority of questions fall into these bolded categories.

2. RECOMMENDED APPROACH TO USING CLICKERS

For questions of the bolded type, we believe it is best to usually follow the following steps:

Step A: Question & Individual Vote

Instructor poses the question, often with some remark about its purpose. Students have time to think about the question individually and answer individually with clicker.

Step B: Peer Discussion

Before seeing the individual vote distribution, students discuss the question in pairs or small groups (Peer Instruction).¹ Instructor moves throughout the classroom, listening in on the discussions.

Step C: Second Vote

Students submit answer using clicker.

Step D: Whole-class Discussion

Instructor and students have follow-up discussion, usually emphasizing the “why” of correct options and “why not” for incorrect options. The instructor should also make sure that any residual issues or student questions from the discussion are explicitly addressed before moving on.

Each of these steps plays important roles in students’ learning processes.

Step A: Question & Individual Vote

By having students answer a question, several “good” things happen:

- i. Focuses students’ attention on (what you consider to be) the important ideas,
- ii. Allows students to try applying ideas they just heard or read about,
- iii. Having to commit to an answer for which they can be held accountable stimulates more intense thought.
- iv. Allows students to build or make connections between ideas or representations,
- v. Gives students an opportunity to analyze a (new) situation or context, and
- vi. Gets students thinking about how to ask questions (that is, it explicitly models the process of analyzing ideas or conclusions by asking questions and figuring out the answers).
- vii. Prepares them to learn. Schwartz and Bransford² have shown that when a person tries to answer a question on a topic they do not know, even when they are quite unsuccessful in obtaining a correct answer, they subsequently learn much more from an explanation of the topic than if they hear the same explanation without preceding the explanation with a question they attempt to answer. This means a clicker question can be valuable when it *precedes* discussion of a topic.

Some instructors don't have students answer individually, but instead move directly to Step B. We recommend having students answer individually, so that the students think for themselves and can't just depend on getting the answers from other students. Research has shown that the students appreciate this step and feel it prepares them to participate in the discussion.³

When posing a question you might experiment with different ways of providing the answer choices. Often it can be good to have the students think about the answer before the answer options are revealed to them. This can discourage them from using test taking strategies to eliminate possible multiple choice options, rather than reasoning through the question as you intended. We have observed in some cases that not seeing the answer possibilities results in students using their notes and making more of an effort to connect the question to prior material. It can also be a good opportunity to make them practice drawing or diagramming something before presenting them with drawings to choose from.

Step B: Peer Discussion

After the individual vote, the instructor tells the students to discuss the question in pairs or small groups. We recommend explicitly telling the students to discuss their *reasoning* for their answer, since that has been shown to result in higher quality student discussion.³

We recommend never showing students the results before the end of the voting period, and not showing students the voting results of the class before peer discussion unless the results show a very wide distribution of opinions with no answer being the obvious favourite. Otherwise, many students will simply change their answer to go with the majority. On the other hand, if there is a 50-50 split in votes, showing students that the question has provoked a split response is an excellent motivator for productive discussion.

What does peer discussion do for students, instructors, and the classroom environment?

Peer discussion:

- i. Actively engages students in thinking about and discussing the concept/skill/idea;
- ii. Improves both their understanding and their ability to communicate technical ideas;
- iii. Gives students an opportunity to explain and defend their reasoning, and analyze others' reasoning (to engage in scientific argument);
- iv. Gives you a chance to hear what students are thinking (listen in on group discussions);
- v. Gives students a chance to voice their questions and hear those of others (realize they are not alone in struggling to master the material);
- vi. Allows students to get help from others to clear up items of confusion; for example, misunderstanding of a technical term that they may have but others around them do not;
- vii. Builds collegial intellectual atmosphere among students (which promotes learning);
- viii. Helps students learn technical terminology by using it in discussion.

Step C: Second Vote

Voting on an answer:

- i. Gets students to commit to an answer and engages them in knowing the right answer. (They are vested in the outcome, but in a peer-anonymous way);
- ii. Provides feedback to faculty (Have the students mastered this idea? Should I move on or spend more time on this topic?);
- iii. Provides feedback to students (Am I understanding this? How does my understanding compare to the rest of the class?)

Step D: Whole-class Discussion

After voting, the instructor leads a whole-class discussion and provides wrap-up for the question. This wrap-up:

- i. Allows you and students to hear students' reasoning for various answers;
- ii. Gives students the chance to hear and respond to each others ideas;
- iii. Gives you the opportunity to emphasize and support reasoning as important ("Why might someone pick B? Why is that answer tempting?", or "Why did your group choose B?" are both somewhat less threatening ways to get students to offer their thinking. However, also telling students they are expected to come up with reasons in their peer discussions, and then calling on students in an obviously random manner to offer up reasons of their group has proven to be effective. This further encourages students to share and critique their reasons during peer group discussions.);
- iv. Allows you to give feedback to the students on their thinking that is both timely and specific, the two elements that research has shown are essential for pedagogically useful feedback;
- v. Promotes understanding of the reasons *why* an answer choice is correct. If discussion focuses upon the thinking associated with right and wrong options, then students will learn *both* about the reasoning underlying the correct answer, *and* what is wrong with incorrect reasoning. (It is important to make sure this happens – correct reasoning for an answer is NOT typically obvious to students, even for many questions that nearly all of them answer correctly.). Finally, this helps students recognize that understanding rather than merely getting a correct answer is what is important both in the course and in the use of clicker questions. Data from our end of term student surveys on clicker use support this.
- vi. Can generate additional questions revealing difficulties that you had not recognized, or introduce elements or applications of the topic that students find interesting and useful.

3. WRITING EFFECTIVE QUESTIONS

Once an instructor has embraced the idea of interactive teaching, having good questions is the single most important element for having a successful class using clickers. Ideally you would like a question that students will interpret properly and will see as interesting and challenging, will stimulate students to want to hear and analyze the ideas of their classmates, will shape student thinking in desired ways, will reveal unanticipated student difficulties or interpretations, and will accurately reveal whether or not students are mastering the material. However, a question can be more than adequate without achieving all these goals, and it is hard to predict which questions will be great until you try them, so it is best not to spend too long agonizing over creating the perfect question.

By far the most common failing is to make questions that are too easy. In this situation, students often see the questions as simply a quiz to keep them awake, and they are annoyed that they had to spend money on clickers only for this purpose. There is also some indication that, in the absence of any other form of feedback, easy questions may mislead students as to the difficulty of the questions they would expect to see on the exam. In extensive surveys of students in many different classes, students overwhelmingly see challenging questions as the most useful for their learning. Our observations have also supported the conclusions that such questions result in greater learning.

Students overwhelmingly see challenging questions as the most useful for their learning.

Usually, the best starting point for obtaining good clicker questions is to look and see what might already be available, either from an instructor who has used clickers in the class previously, or in one of a number of online repositories for such questions. The instructor's guides to many textbooks now offer lists of questions. These can be an easily accessible starting point for finding questions, but these textbook questions unfortunately are often quite simple and factual.

The best way for finding online repositories of questions is to type "ConcepTests" (the label chosen by Eric Mazur who developed this method of instruction) into Google. This brings up listings of question collections in numerous fields. Also, see:

<http://cwsei.ubc.ca/resources/clickers.htm#questions> for some links to clicker question collections for science and math.

From in-class observations of instructor lectures, we have noticed several places to find good clicker questions. You can try to pick up on these yourself, or you might find it helpful to invite a colleague or graduate student to observe a few lectures.

A. Questions professors pose to the students spontaneously during class. These questions often cover the points they want to get across and/or have an interesting example that can help students associate what they are learning in class with the real world (for example: a disease, exercise, aging). To record these questions, professors can have TAs sit in on their lectures and write them down along with any responses offered by students.

B. Overhearing student discussions about questions posed in class. Listening to students' discussion and what they are thinking as they generate their answers often suggests good questions. Also, these discussions often suggest points that students are confused about and hence would be good incorrect answers to list and subsequently discuss. Professors can wander during this time, join a group discussion, and have a TA record and move around the classroom.

C. Questions students pose in class can also be turned into excellent clicker questions. Although usually an instructor will make this a question in a subsequent class or term, don't be afraid to do this in real time, by taking a question that a student has asked and throw it back to the entire class to answer. You can either create your own multiple choice answers on the spot, or get suggestions from students. This is a particularly good thing to do when the question raises an important point and you are pretty sure that most students can figure out the answer.

D. Dealing with connections. We frequently observe that students fail to make connections between new and previously learned concepts as well as connecting material with general themes in the course as a whole. Clicker questions can make these connections explicit.

E. Analogies. Professors have many great analogies they use in lecture. These can provide a good basis for clicker questions.

While testing the question with students is the only way to find out if it is effective (in terms of promoting student learning, uncovering misconceptions, and generating student engagement and discussion) you can stack the odds in your favor by considering the following points.

1. Define your *learning goal* or *objectives*.
What you want students to be able to do (in terms of using content and skills, etc.)?
2. Identify the *goal(s)* of the clicker question.
3. Choose type of question to use (see below for some options under "tactics").

Example from Geology 1010:

1. Learning goal (*What you want students to be able to do?*):

Explain and demonstrate how geologists determine rates of tectonic plate motion from data on seafloor age.

Skills: calculating a rate, reasoning like a geologist, developing competence using geological data, interpreting a representation commonly encountered (but seldom explicitly explained) in textbooks

Concepts: tectonic plates move: the rate of past plate motion at spreading centers (divergent plate boundaries) is known from the age of oceanic crust making up the seafloor.

2. Goal(s) of the clicker question

Promote articulation/discussion, stimulate cognitive processes

3. Tactic or tactics to use

Qualitative question, analysis and reasoning, interpret representation, rank variants.

4. Clicker question

The resulting clicker question had students to look at a map of the earth showing the ages of the seafloors, and students were asked to rank the relative speeds of the plates at various locations.

Beatty et al.⁴ have discussed tactics to use in designing relatively advanced clicker questions. These are primarily of use to instructors experienced at using clicker questions.

Question design goals and tactics (Beatty et al., 2006)

Question design goals	Tactics
Direct attention and raise awareness	<ul style="list-style-type: none"> - Remove nonessentials - Compare and contrast - Extend the context - Reuse familiar question situations - Oops-go-back
Promote articulation/discussion	<ul style="list-style-type: none"> - Qualitative questions - Analysis and reasoning questions - Multiple defensible answers - Require unstated assumptions - Trap unjustified assumption - Deliberate ambiguity - Trolling for misconceptions
Stimulate cognitive processes	<ul style="list-style-type: none"> - Interpret representations - Compare and contrast - Extend the context - Identify a set - Rank variants - Reveal a better way - Strategize only - Include extraneous information - Omit necessary information
Formative use of response data	<ul style="list-style-type: none"> - Answer choices reveal likely difficulties - Use "none of the above"
We add: Connect to the real world	<ul style="list-style-type: none"> - Apply to real world setting - Pose in terms of real world problem

4. INTRODUCING STUDENTS TO THE USE OF CLICKERS

On the first day, you should talk to your class about why and how you are using clickers and what the value is for their learning. This is most important in a setting when students have never used clickers before. You should discuss how clickers will improve your communication with them, the well-established value to learning when students actively engaged in thinking about the subject and figuring out answers to questions, and how clickers make this much easier to achieve in a lecture setting. You could mention that extensive surveys of students who have completed courses that used clickers in this way have shown that students enthusiastically support their use in lectures.

One approach to making these points is to start with a “Why do you think we use clickers” clicker question in class, as shown below. Possible answers are all components of “active learning” and hopefully you will see a spread of answers. The post question discussion can then allow you to bring out why these are all good reasons.

[Clickers] mentally engage [students] with the concepts so that the lecture is not just passive listening and note taking.

What do you think is the single most important reason that I am using clickers?

Possible answers:

- a. promotes your ability to communicate your ideas.*
- b. strengthens your ability to debate and defend your answers, and to suggest improvements.*
- c. promotes peer discussion that is balanced, with ideas put forth evenly from both partners.*
- d. promotes a safe environment for you to answer what you honestly think, rather than answering what you think the instructor wants.*
- e. gives you feedback on how well you understand a topic.*
- f. gives me as your instructor feedback on what needs to be taught better, or expanded upon.*
- g. encourages you to mentally engage with the concepts so that the lecture is not just passive listening and note taking.*
- h. encourages attendance.*

5. LOGISTICS

Grading and timing issues (and recommended approaches are described in the “Frequently asked questions” at the end of this paper.

Student peer groups: There are three main ways of setting up student peer (discussion groups. Instructors have discovered pros and cons for each method with respect to set-up, ease and quality of student discussions, and student response, summarized below. In typical theater-style lecture room, maximum group size should be no more than four students in adjacent seats, and optimum is 3. Discussion involving 3 or 4 people is often more substantial than with only two. With formal groups it can be effective to announce on some questions that groups are required to reach consensus, thus voting the same. This strategy substantially increases the amount of discussion and being able to do this is one of the primary virtues of formal groups. This works even if one never checks if group actually did reach consensus.

Formal group (instructor-defined):

Pros	Cons
<ul style="list-style-type: none"> - Good student conversation - Focus of discussion more on topic 	<ul style="list-style-type: none"> - Takes time to set up - Minor student complaints (major if not done early in term and reasons for doing not explained first day!) - Early discussions may be “sluggish” as they get to know each other

Formal group (self-assembled):

Pros	Cons
<ul style="list-style-type: none"> - Few student complaints - Little hassle - computerized signup - Better discussion than no formal groups 	<ul style="list-style-type: none"> - Can be more off-topic discussions

Informal (neighbours only):

Pros	Cons
<ul style="list-style-type: none"> - Few student complaints - No hassles 	<ul style="list-style-type: none"> - Many students not very involved - More off-topic discussions (about weekend)

6. COVERAGE OF MATERIAL

Using clickers extensively may reduce the amount of content you can cover during class, as will any classroom intervention promoting mentally active learning. Clickers also typically result in far more and deeper questions from a broader range of students, because they are more engaged in thinking about the material. Responding to those questions takes additional time. However, while the coverage of material in class may be reduced, there is good evidence that the learning will be considerably increased. Multiple studies across a variety of disciplines show that students in courses incorporating active learning retain and can apply important concepts better than students taught in traditional lectures.^{1,5}

[With clickers, students] are more engaged in thinking about the material...Clicker use also promotes more in-depth learning and understanding.

This provides students with a greater capacity to cover topics on their own; for example, they can be capable of doing homework questions on topics that were not covered in class. Having them learn material outside of class in this way can compensate for the reduced coverage in class.

Also, much of the time in a traditional lecture is spent providing students with information that they can easily get elsewhere and, in some cases, repeating information students already know. Clicker questions allow one to better gauge what students know and thereby avoid unnecessary repetition of coverage. If used appropriately, the questions can also compel students to read material to learn basic information before coming to class.

While these strategies can increase the amount of material covered in a course, nevertheless, we have seen that most instructors do end up deciding to cover slightly (~10%) less material in their courses after they have started using clickers effectively. However, this is usually a choice made as a result of their recognizing that it takes longer than they had realized for the students to achieve the desired learning. This recognition is a result of the improved communication made possible through their use of clickers.

7. DEALING WITH UNEXPECTED SITUATIONS

An instructor who has not used clickers before may encounter three novel situations. These can be positive experiences if you are ready for them and respond accordingly, but can be quite negative if you are not.

- 1) **You have given the clearest explanation you know how, yet it is obvious from responses to a clicker question that students are not getting it.** When you try to give up and go on, students respond assertively, saying that it is obvious they don't understand this and you need to teach it right before going on.

In dealing with this situation, the most important thing to keep in mind is that it happens, so be prepared for it and don't panic. Recognize that it is not entirely

A good clicker question and discussion generates far more and deeper questions from students than encountered in a non-clicker class.

negative; it indicates that students are taking much more responsibility for their learning and setting higher expectations for learning than in a traditional course. Chastising the class for being unprepared, stupid, or inattentive (even if some of this is true) produces quite negative reactions. If you find yourself unable to figure out in real time how to clarify the point by presenting it in a different way, try to find a student in the class who can clarify and/or address their confusion. If that fails, then just admit to the class that you are stuck, and say you will return to this point in the next class after more thought. Encourage the students to do the same. Then make sure you do return to the topic as promised.

- 2) **You are asked a question that is sufficiently deep that you do not know the answer.** A good clicker question and discussion generates far more and deeper questions from students than encountered in a non-clicker class, so this is a much more likely occurrence when using clickers.

Deal with this as in case 1. Admit you do not know the answer, say that you will research the subject to try to figure out the answer by next class, and encourage the students to do the same. At start of next class, see if any students came up with the answer, and if not provide the answer you figured out. It is particularly valuable if you are quite explicit in explaining what was challenging about the question, and how you went about finding out or figuring out the answer. This models expert thinking in a way students very seldom get to see and they often find quite memorable when it is displayed in cases like this. Of course, explicitly modeling expert problem solving in this way is also beneficial when answering clicker questions, but it is seldom as memorable for students as when there is a question they saw you could not answer initially.

3) There are so many good questions that you do not see how you can answer them and come close to getting through all the material you planned to cover that day.

Again, this should be seen as a positive event. The best indicator of a good clicker question is probably how many thoughtful follow up questions it generates. For this case of “too many” questions, the first thing you should do is analyze how many of the students are asking questions. If it is a relatively small number and they are the students who frequently ask questions, it is likely rest of class will be annoyed if too much time is spent on answering questions from that group. Then it is best to tell those students you will talk with them individually after class or during your office hours, and move on. However, if you have a situation that is fairly unique to clicker classes, where there are questions from many students, including those who do not frequently ask questions, you should remember that when a substantial fraction of the class is interested and asking questions, they will learn much more from what you tell them in response to those questions at that time than anything else you can teach them. Also remind yourself that their interest in and learning of the subject is more important than your covering the topics in the order and pace you had originally planned. So adjust your lesson accordingly in real time.

Multiple Goals of Using Clickers

1. Engage students in active learning:
 - Apply ideas/skills/problem solving immediately in class;
 - Predict outcomes;
 - Reason in new contexts;
 - Draw connections between ideas.
2. Promote student-student discussion
 - Create a collaborative spirit for supporting learning;
 - Practice justifying a position/responding to arguments;
 - Practice monitoring their own thinking;
 - Aid their learning of technical terminology by using it in discussion.
3. Provide feedback to the instructor about students understanding.
4. Provide feedback to the students about their own understanding, both through their seeing the histogram of responses and in follow up discussion by instructor.
5. Use as formative assessment to guide teaching (measure what students are thinking and then address it): e.g. probe prior knowledge, probe current thinking, uncover student misconceptions.
6. Listen to students' ideas as they discuss and reason about the material.
7. Give students a voice: e.g., survey what they want to learn about most, when to have homework due, some grading policies, when and where to have homework study sessions, if and how to review for exams,...
8. Facilitate student accountability for attendance and reading textbook to prepare for class (quizzes on reading).
9. Model the process of critical thinking through asking questions and figuring out answers in order to promote students doing this themselves.
10. Ensure instructors have not lost touch with what students are understanding and that pace of class is appropriate.
11. Get students to commit to an answer (they are vested in the outcome).
12. Reaffirm learning (positive feedback, review material, etc.).
13. Survey students' background.
14. Send a message that instructor's priority is student learning.

Frequently Asked Questions About the Use of Clickers and Clicker Questions

1. How much time should I give students to answer a clicker question?

This depends greatly on the type and difficulty of the question: in most cases, it takes students between 30 seconds and a minute to process a question and be ready to answer individually or discuss. It then takes a few (1-4) minutes for productive discussion. The level of student discussion and the number of votes in is a good guide as to when to move on. When ~3/4 of the students have responded it is often a good time to announce end is near, then sound warning gong, count down out loud, or turn lights out to indicate that discussion should stop and students should “click in”. Instructors who decide when to end the polling based on the discussion around them often wait too long. While discussion around them will continue to focus on the question, in the rest of the room discussion has often moved on to non-class-related topics, making it harder to pull students back to class material. It is useful to poll the class after several weeks to see if they feel you are giving them too little or too much time.

Using the timer in the countdown mode available with most clicker system software is usually distracting to students and instructors and can limit discussion. It is better to set the timer to the maximum count down duration or in count up mode, and then just stop the question manually when you think it's appropriate.

2. How should clicker questions be graded?

Most instructors make clicker questions a portion of the total course grade; between a few % and 15% is common, although a wide variety of approaches are used. The two most common grading schemes used are giving equal credit for correct and incorrect responses (participation only), and giving greater credit for correct than incorrect responses. Some pros and cons to these grading approaches are listed below. Another approach is to give participation credit only most of the time, but occasionally grade individual questions for correct responses. There is no consensus view recommended by research or convention, but our anecdotal observations lead us to lean towards this latter grading policy of always giving credit for participation and occasionally giving additional reward for the correct answer.

Giving credit only for correct responses is not recommended as it distorts the discussion and student response strategies in undesirable directions,⁶ and it limits the type of question that can be asked. For example, you cannot ask questions with multiple justifiable answers; yet such questions can generate the most educationally productive discussions. Similarly, not having clicker questions count for any credit is not recommended.⁷ This sends the message that questions and answers are not important, and students will not take them seriously.

Although student responses will vary, our observations suggest the specific grading policies do not make very much difference to students as long as one avoids the extremes that result in undesirable outcomes listed above. As long as there are consistent implicit messages from the instructor that the questions matter, students seem to take the questions reasonably seriously.

Some clicker questions should NOT be graded for the “correct” response but are very useful in promoting discussion, student learning, and instructor and student feedback.

Regardless of grading scheme, some clicker questions should NOT be graded for the “correct” response but are very useful in promoting discussion, student learning, and instructor and student feedback. Examples of such questions are those with more than one potentially correct response, and those intended to elicit student misconceptions or students’ prior knowledge.

We also highly recommend that whatever grading policy is used, a certain number (2-3) of “free” days are allowed. These are days for which the student will get credit even if there are no clicker responses recorded for them. This greatly reduces the time student and instructor need to spend dealing with complaints/excuses about clickers not working, being forgotten, missing class due to any number of catastrophic events beyond students control, etc. An alternative that is similar in concept is to set a certain percentage of questions students need to answer, such as 80 or 90%, and once above that threshold they receive “maximum clicker credit”. We have also seen that when clickers count for more than 15% of the grade, the amount of time spent dealing with student concerns about being sure they receive credit for clicker responses can get annoying. Finally we recommend that at the beginning of the course you should very clearly announce that use of another person’s clicker, or having someone use your clicker, is considered cheating with the same policies applying as would be the case for turning in illicit written work.

Common grading policy	Pros	Cons
<p>Equal credit for correct and incorrect responses (e.g. 2 pts per response or 2 pts total per class)</p>	<ul style="list-style-type: none"> - Promotes balanced peer discussion, ideas put forth evenly from students - Promotes a safe environment for students to answer what they honestly think rather than answering what they think the instructor wants. 	<ul style="list-style-type: none"> - Less incentive to pay attention, think through a question, and commit to an answer.
<p>More credit for correct responses, some credit for any response (e.g. 3 pts correct / 2pts incorrect)</p>	<ul style="list-style-type: none"> - More incentive to pay attention and actively work out an answer if the question is graded. 	<ul style="list-style-type: none"> - Students may feel pressured to get the right answer, less incentive to share own reasoning and discuss honestly. - Promotes unbalanced peer discussion, more knowledgeable students can dominate discussion. - Promotes memorization of answers from previous Terms. - Not appropriate for all types of questions.
<p>Mixed: Many participation only questions, some graded questions. (e.g. 2 pts per class for participation + 1 pt on graded questions if correct)</p>	<ul style="list-style-type: none"> - Promotes process and reasoning of figuring out answer. - Allows flexibility to grade only questions that are summative assessments. - Having some graded questions keep students' attention. 	<ul style="list-style-type: none"> - More set-up or post-analysis to identify which are graded and which are participation only (is fairly easy with some clicker software, not with some others).

3. How many clicker questions should I give in a lecture?

Most instructors find that between four and six questions that involve serious discussion and reflection in a 50-minute class period works well. These should be distributed throughout the lecture rather than all clumped at beginning or end. In general, students' attention often starts waning after about 10 minutes of straight lecturing. If one is using other active learning techniques in a lecture period, the number of clicker questions will likely be lower. For a review before an exam, it can often be more effective to fill the lecture period with many clicker questions rather than using other types of review.

4. How do I promote discussion between students?

Achieving good discussion between students is often the hardest but most important part to maximizing the benefit of clickers. This is a change in the culture of the class, and so you should not expect it to happen automatically. You should not give up if it takes a little while to develop, and you should actively encourage it, and explain and model scientific discourse for them.

On the first day and a couple of subsequent days, encourage the students to learn the names and shake hands with everyone around them (in front and behind included). Also giving the students permission to ask names they've forgotten can be surprisingly helpful. We may not be able to learn the names of the whole class, but students appreciate knowing someone knows their name.

Students need to feel that the classroom is a safe place to discuss questions, and everyone can potentially be wrong without consequences. Instructors can promote this by explicitly informing students of what they expect and why the interactive/discussion approach helps students learn. This should be done repeatedly during the term as opposed to just at the beginning. We recommend that you also tell students that you'll be asking them to share their reasoning about the answer so they should discuss it, and then have them share their reasoning at least some of the time in the follow up whole class discussion.

Some techniques for directly encouraging discussion are to require groups to submit consensus votes on a question. Calling on students to ask them what reason their group gave for why an answer is correct or incorrect can also help. Students find it less threatening to offer the reasoning for an answer if the answer is seen as coming from the group rather than them, individually. If possible, it's good to also require students to give reasons for answers on homework and exams.

5. What should I do while students are discussing?

Walk around room and listen to discussions. Briefly intervene to encourage discussion, involve more students, or answer questions. Avoid interacting too long with one group.

6. Don't "strong" students just give "weak" students the answer if there is discussion?

Research suggests that this isn't a great concern, and that both "strong" and "weak" students benefit from interacting in peer discussion.⁸ However, studies⁶ have shown that the way credit is given for answering questions can impact this. In a class with "low stakes" grading (equal credit for any response), peer discussion was more balanced, with both students in a pair contributing

equally to discussion and more likely to vote differently. In contrast, a class with "high stakes" grading (incorrect responses earning 1/3rd the credit

earned by a correct response), students earning higher grades tend to dominate peer discussion, and both students in a discussion pair more often voted the same. In a small study we did in a different course, we found the correlation between students clicker question answers and their course grade was surprisingly low, indicating that as students were first learning new material, there was little distinction between "weak" and "strong" students. No matter what the achievement level of the student is, encouraging them to articulate their thinking is beneficial.

No matter what the achievement level of the student is, encouraging them to articulate their thinking is beneficial.

7. How do I get students to stop talking after a clicker question?

A good signal that students are finishing their discussions is when the voting gets up towards 75% of the class. If you wait for everyone to vote, you are waiting too long. If less than 75% have voted, you haven't waited long enough. Having an established signal for when discussion needs to end works well, such as a gong tone, whistle, or switching off the lights.

8. Are clickers any better than other classroom response systems?

Andrea Bair and colleagues of the CU-SEI conducted a study comparing use of identical questions in two sections of the same course, but using clickers in one and raising hands in the other. She found substantial differences, all favoring use of clickers.⁹ We have also observed a number of courses where colored cards were used and then the same instructor switched to using clickers. Although there were similar benefits to using questions posed to the class and requiring students to respond using their colored cards, attendance and student engagement was significantly higher when clickers were used. In interviews and surveys, students make it very clear that they see clickers as providing a more useful and legitimate way of determining student understanding, and hence more valuable than using cards. The combination of anonymity and accountability is a major virtue of clickers. In the words of one student, *“I thought that clickers were helpful. It made it easier for the teacher to see how many people actually understood what we were talking about without embarrassing anyone and picking on them.”*

“I thought that clickers were helpful. It made it easier for the teacher to see how many people actually understood what we were talking about without embarrassing anyone and picking on them.”

Internet and cell phone systems are available that allow more complex responses and are potentially less expensive. However, there is significant potential for distraction and cognitive overload—for students and instructors—with these systems. Good clicker questions with peer discussion and instructor follow-up can stimulate deep and complex thinking.

9. Will there be student resistance and if so, how do I deal with it?

Some students may resist the change in classroom climate from a passive to a more active environment, particularly as it penalizes absences and requires more effort. Most respond well if the instructor explicitly (and repeatedly!) talks with the class about the purpose of using clickers interactively, and emphasizes the positive results seen in other classes and education research. The implicit signals are also very important. When the clicker responses show students do not understand something, revising the lecture plan to examine their difficulties and address them, rather than ignoring this, sends a very positive signal. *Requiring students to spend money on clickers and then using them only once or twice per class to answer very simple questions sends a very different signal and can generate considerable student unhappiness.*

We have done extensive surveys of students in classes that use clickers. In those classes where the clickers are used in a manner at all close to what we recommend, the students overwhelmingly say they contribute to their learning and recommend they be used. It helps both learning and attitudes if you ensure that the clicker questions, homework, and exam questions indicate in a consistent manner what is important and what the expectations and standards are for the course.

There can be a few very vocal students who strongly oppose clickers, but our surveys have shown that when clickers are used well, this view is never shared by more than a small minority. If they are troublesome, their complaints can be reduced by surveying the class to show that they are a small minority, rather than representing the sentiment of all (as they usually assume). Also, although most students say they like using clickers, even those who do not often still recognize their value. In the words of one such student we interviewed, *"Using clickers is like broccoli – I don't like it, but it's good for me."*

Finally, the most effective way to eliminate student resistance ultimately is simply to use clickers to make the classroom an extremely stimulating place where students are highly engaged and learning a great deal.

10. Won't I lose control of the class if I let them talk so freely?

This is not as big a concern in practice as it is feared to be. There certainly is less rigid control of the class, but students also see the class as more supportive of their learning, and so they are more on your side from the beginning. It is helpful to lay out some ground rules clearly. Along with the reasons for having clicker questions and discussion, make it clear that discussion is supposed to be limited to the subject material (even though it will not always be, and that when you have signaled it is time for discussion to stop, they should do so, and any questions remaining at that time should be directed at you. As the term progresses and students get to know each other better and become more comfortable talking to each other, it usually does get more difficult to cut off discussion. Training students from the beginning to respond to some signal like a gong or lights flashing markedly reduces the difficulties and is normally adequate.

If just a few students continue to talk, ask them directly in front of the class in a non-confrontational way, if they have a question. If they are discussing non-class related material that will quiet them then and in the future. If they are discussing the class material, which is more typical, they will ask a question which you can treat like a regular question, and still send the message clearly that they were disruptive. It is unlikely, but not impossible that you may have an exceptionally unruly class where even these steps are not sufficient to quiet

them down. (It is not clear whether such classes are made worse or better with clickers.) A reasonable approach we have seen for that case is, if class is not quiet after the gong/signal, simply stand there looking at them and wait. If they continue to talk, make it clear that students will be responsible for material not covered because of the time you spent waiting for class to quiet down, and then when there are subsequent disruptions, just continue to wait them out and rely on student peer pressure to deal with the noisy students.

11. How do I respond if technical problems arise during class?

Reassure students that technical problems in no way impact any grading scheme you have implemented. Then pose the question anyway and have discussions as originally planned, and ask for the show-of-hands approach to answering. Results can be tallied (even if roughly) on paper, the blackboard, or an overhead projector.

12. Should I post answers to clicker questions after class or not?

There are varying opinions about this and no data that indicates one way or another. However the work in reference 2 shows that when people have the answer explained to them after they have thought hard about how to answer the question, they learn a large amount from the explanation. On the basis of that research, our inclination is that it is probably better to post the answers.

13. Do clickers work in upper level as well as introductory courses?

We have several examples of instructors who began using clickers in large introductory courses and then tried them in smaller upper level and even graduate courses. They are very enthusiastic about the results, and students in upper level clicker courses strongly supported this use on our surveys.

In summary, we have found the effective use of clicker questions and discussion can have a transformative impact on both teachers and students, particularly in large classes. Students end up being far more actively engaged in the material and they learn more, and both students and instructors find the course much more rewarding as a result. If you are currently using clickers, we hope this guide will give you ideas on how to use them more effectively, and if you have not yet tried them, we hope this will provide you with the encouragement and assistance to use them effectively.

Appendix

Examples of good practice

General Ex. 1 **Question that encourages good discussion.** The first question the instructor asks is a question where all the answers are partly right. This produces a nice spread of answers, and students are confident to discuss with the instructor and argue with their peers about the correct answer, (because they were all right) and about what parts of the other answers are incorrect (because they were all partly wrong).

General Ex. 2. **Use of student polls.** “What topics do you find most interesting?” “Would you like exam review sessions?” Such questions are a good way to (a) demonstrate the diversity (or similarities) of opinion in the class; (b) determine directions for future lessons or activities (thus giving some measure of content-ownership to students); (c) demonstrate a match between opinions or interests and the course itself (useful during the first week of the course). We recommend making results of such poll questions visible to students and using the results in some fashion. This could include referring back to those results in pre- and post-question discussions, or making changes in response to type (b) questions with explicit indications of how the survey results influenced the changes.

Examples of specific good clicker questions from range of courses.

Environmental Science course

This question was presented during the class meeting AFTER students had completed and had returned to them a graded homework assignment in which they were asked to plot and interpret hydrologic data.

Clicker Question: Who knows more about a set of data?

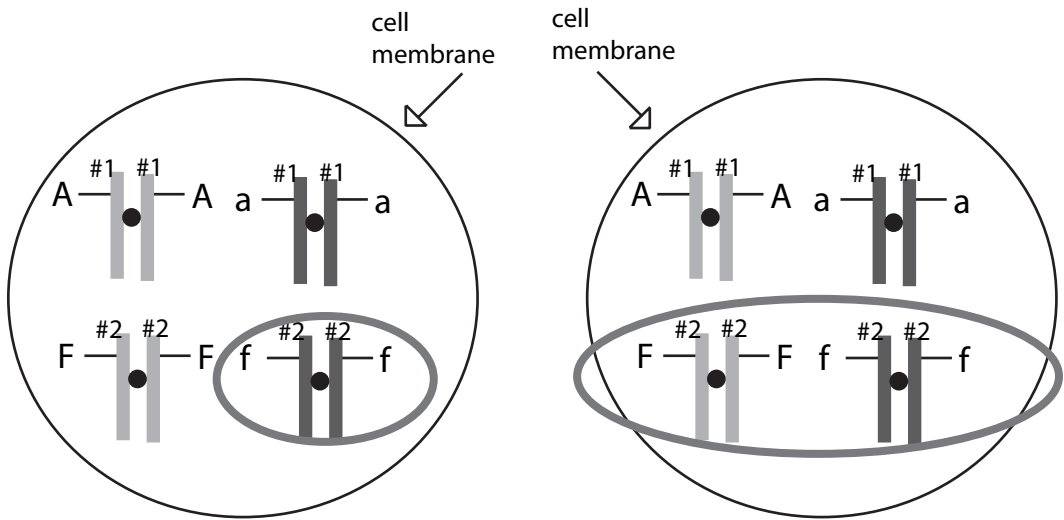
Answer choices (*results prior to discussion*):

- (a) the person collects it (~10%),
- (b) the person who plots it (~90%)

This clicker question was used as spring board into talking about the HW assignment. During the discussion students greatly changed their original opinion about who knew more about the data. That discussion then acted as segue into the next lecture topic on using hydrologic data to predict flooding.

Genetics course

A series of clicker questions can reveal that although students understand parts of a topic they still have misunderstandings about it.



Sister Chromatids

1. Do they have the same set of genes?

- A. Yes 100%
- B. No

2. Do they have the same alleles?

- A. Yes 100%
- B. No

4. You grow sweet peas. One of your clients wants purple sweet peas for her wedding. Which two sweet peas should you cross in order to maximize the number of purple sweet peas in the next generation?

- A. Purple CcPp x Purple CcPp
- B. White CCpp x White ccPP
- C. Purple CcPp x White ccPP
- D. Purple CcPp x White CCpp

Homologous Chromosomes

3. Do they have the same set of genes?

- A. Yes 46%
- B. No 54%

Introductory Biology course.

1. A plasmid containing bacterial DNA and the gene for human growth hormone is introduced into a bacterium. Which growth hormone protein will be produced?
- A. A bacterial human growth hormone protein
 - B. A human growth hormone protein
 - C. A hybrid protein that is part human and part bacterial

Answer: B

2. The production of a human protein in a bacterium can occur because:
- A. Humans and bacteria use the same codons to specify each amino acid.
 - B. Humans and bacteria use almost the same codons to specify each amino acid.
 - C. Humans and bacteria use different codons to specify each amino acid, but there is enough similarity that the protein made in bacteria still works.

Answer: A

3. Which of the following statement is true? All the somatic cells (the cells that do not contribute to the next generation) in your body contain:
- A. The same DNA sequences and the same proteins
 - B. Different DNA sequences and different proteins
 - C. The same DNA sequences but different proteins
 - D. Different DNA sequences but the same proteins

Answer: C

4. If an organism makes an abnormal protein, the error that led to this abnormality most likely originated
- A. during replication of the corresponding gene.
 - B. during transcription of the corresponding gene to make the corresponding mRNA.
 - C. during translation of the corresponding mRNA to make the protein.

Answer: A

5. Which of the following is a FALSE statement about bacteria and viruses?
- A. Viruses are cells.
 - B. Viruses replicate inside human cells.
 - C. Bacteria can replicate their own DNA.
 - D. Viruses can have RNA as genetic material.

Answer: A

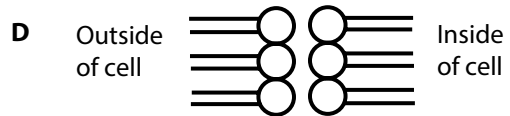
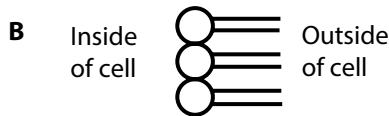
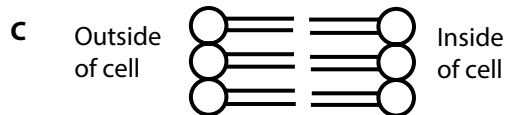
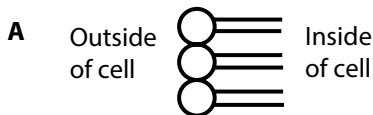
6. Should you take an antibiotic if you have a viral infection?

- A. Yes, an antibiotic could kill the virus
- B. No, an antibiotic can only kill bacteria

Answer: B

7. Draw a representation of the plasma membrane using circles and lines to represent the two “ends” of the phospholipids that comprise the membrane. Indicate the inside and outside of the cell with respect to the membrane. {Allow students to work on this drawing for a few minutes. Then, ask the following question:}

Which of the following illustrations looks most like your own drawing (or looks correct now that you see it)?



Answer: C

Physics course

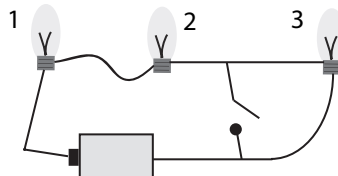
1. You have a ring with a hole in it and a cylindrical plug that is exactly the same size when both are at room temperature. If you heat the ring, the plug will

- A. Fit through the hole more easily
- B. Fit exactly the same as before
- C. No longer fit through the hole

This question can be followed by a demonstration involving actual ring that you heat, if you choose.

2. When you close the switch, bulb # 2 will

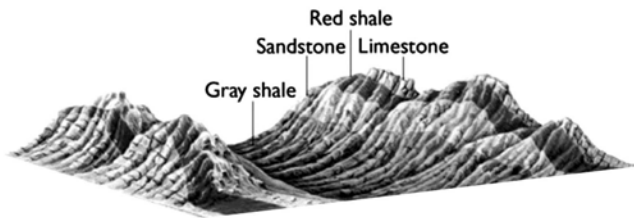
- A. Get brighter
- B. Get dimmer
- C. Stay the same brightness
- D. Go out entirely



Geology course example – Using learning difficulties (including misconceptions) in teaching:

Students often have difficulty identifying structural features which have undergone erosion (and with visualizations that are different than the standard textbook block diagrams). One common misconception is that structural features will follow topography; additionally, students generally don't understand what kind of information is necessary to distinguish types of folds. Here's a (faculty-developed) clicker question that promotes student examination and explanation of their own reasoning:

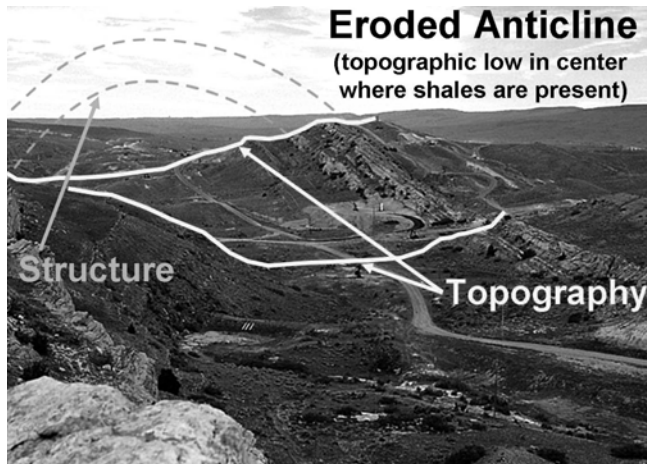
What additional information would you prefer in order to determine if the exposed geologic formations correspond to an anticline or a syncline?



- A. Formation ages, rock compositions
- B. Strike and dip measurements, formation ages
- C. Rock compositions, fossil content
- D. None of the above

Why this works

The above figure could be interpreted as either a syncline or an anticline [*types of folds in rocks; synclines occur when rock layers curve upwards, and anticlines are characterized by rock layers*



curving downwards], and can't be determined based only on the given information. This formulation helps students identify their conception that topography follows structure. A follow-up example is given on the left, which helps students solidify the use of correct reasoning, identify types of geologic information necessary for solving this problem, and gain experience interpreting different representations of geologic features.

References

General references

- E. Ribbens, "Case Study: Why I like clicker personal response systems," *J. of Coll. Sci. Teaching*, 37(2), p. 60, (2007).
- D. Duncan, *Clickers in the classroom: how to enhance science teaching using classroom response systems*, (San Francisco: Addison Wesley and Benjamin Cummings, 2005).
-

- ¹ C. Crouch, J. Watkins, A. Fagen, and E. Mazur, "Peer Instruction: Engaging Students One-on-One, All At Once," *Research-Based Reform of University Physics*, 1 (1) (2007) [<http://www.compadre.org/Repository/document/ServeFile.cfm?ID=4990&DocID=241>]; E. Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, NJ, 1997).
- ² D. Schwartz and J. Bransford, A time for telling, *Cognition and Instruction*, 16, 475 (1998). [https://aaalab.stanford.edu/assets/papers/earlier/A_time_for_telling.pdf]
- ³ T. Vickrey et al., "Research-Based Implementation of Peer Instruction: A Literature Review," *CBE—Life Sciences Education*, 14, p. 1 (2015).
- ⁴ I. Beatty, W. Gerace, W. Leonard, and R. Dufresne, "Designing effective questions for classroom response system teaching," *American J. of Physics*, 74(1), pp. 31-39 (2006).
- ⁵ S. Freeman et al., "Active learning increases student performance in science, engineering, and mathematics," *Natl. Acad. Sci. USA* 111:8410–8415 (2014); *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (Washington, DC: National Academies Press, 2012); R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. of Physics*, 66(1), p. 64 (1998); L. Deslauriers, E. Schelew, and C. Wieman, "Improved learning in a large enrollment physics class," *Science* 332:862–864 (2011); J. Knight and W. Wood, "Teaching more by lecturing less," *Cell Biol. Educ.* 4, p. 298 (2005).
- ⁶ M. James, "The effect of grading incentive on student discourse in Peer Instruction," *American Journal of Physics*, 74(8), pp. 689-691 (2006); M. James and S. Willoughby, "Listening to student conversations during clicker questions: What you have not heard might surprise you!," *Am. J. Phys.* 79(1), pp. 123-132 (2011).
- ⁷ S. Freeman et al., "Prescribed Active Learning Increases Performance in Introductory Biology," *CBE Life Sci Educ.* 6(2), pp. 132-9 (2007).
- ⁸ M. Smith et al., "Why Peer Discussion Improves Student Performance on In-Class Concept Questions," *Science*, 323(5910), pp. 122-124 (2009); M. Smith, W. Wood, K. Krauter, and J. Knight, "Combining Peer Discussion with Instructor Explanation Increases Student Learning from In-Class Concept Questions," *CBE Life Sci Educ.*, 10(1), pp. 55-63 (2011).
- ⁹ Poster available at: www.cwsei.ubc.ca/resources/clickers.htm

more references and other resources at: www.cwsei.ubc.ca/resources/clickers.htm

For an electronic copy of this Guide, plus information and resources
– including videos of clickers in action –
please visit:

STEMclickers.colorado.edu

This guide was prepared by staff & associates of the Carl Wieman Science Education Initiative (CWSEI) and The Science Education Initiative at the University of Colorado (CU-SEI):

CWSEI
University of British Columbia
Vancouver
<http://www.cwsei.ubc.ca/>

CU-SEI
University of Colorado
Boulder
<http://www.colorado.edu/sei/>