

# Supplemental Material

*CBE—Life Sciences Education*

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## Supplementary Material

### Survey Questions

**Directions:** Please take a few minutes to complete the following survey. Your responses to these questions will help your instructor understand your thoughts on the class.

The questions on the next two pages ask about [these FAs], which are defined as [insert descriptive definition of the FA type].

Why do you think [these FAs] are used in this course?

How has the use of [these FAs] influenced your learning in this course?

How has the use of [these FAs] influenced your instructor's teaching in this course?

To what extent do you agree or disagree with the following statements? (Likert choices: strongly disagree, disagree, neither agree nor disagree, agree, strongly agree)

Overall, [these FAs] are beneficial to me.

Overall, [these FAs] are beneficial to the instructor.

[These FAs] help me identify what material I am expected to learn in this course.

[These FAs] help me understand what it takes to be successful in this course.

[These FAs] give me feedback on what I still need to learn in this course.

[These FAs] help me take control of my own learning in this course.

[These FAs] give the instructor feedback on how well students understand course material.

How often do you discuss [these FA] questions with other students? (Likert choices: never, rarely, sometimes, often, always)

To what extent do you agree or disagree with the following statement? (Likert choices: strongly disagree, disagree, neither agree nor disagree, agree, strongly agree)

Discussing [these FA] questions with other students helps me learn in this course.

How might the use of [these FAs] be changed to improve your learning in this course?

**Supplementary Table 1.** Definitions and sample student responses for each of the response categories for three of the open-ended questions. Dots indicate that a given response category was coded for the indicated question. *Purpose* refers to the question, “Why do you think [these FAs] are used in this course?” *Learning* refers to the question, “How has the use of [these FAs] influenced your learning in this course?” *Teaching* refers to the question, “How has the use of [these FAs] influenced your instructor’s teaching in this course?”

Response category	Open-ended question			Definition	Example student responses
	Purpose	Learning	Teaching		
Clarifies learning intentions and criteria for success	•	•	•	The FA clarifies what students are expected to learn in the course or how to be successful in the course.	“It gives me a clue on what I should be getting out of the lectures, and also allows me to see what could be on the test.” “It allows him to ask questions he feels are important for his students to know.”
Provides general assessment	•			The FA is used for assessment of knowledge or learning, but the student does not make it clear whether this information is for students or the instructor.	“To determine level of knowledge on a topic.” “To test our understanding of the concepts that we have recently gone over in class.”
Gives instructor evidence of student understanding	•		•	The FA gives the instructor feedback about their teaching or about what students understand.	“It gives instructors feedback for what students do not understand.” “help the professor know what we’re getting from lecture.”
Changes instruction based on student understanding	•		•	The FA leads the instructor to change their instruction (e.g., how something is explained, how much time is spent, etc.) based on the evidence of student understanding gained by the FA.	“influences what he stresses during lecture based on how well the class already understands the material.” “if there is a misunderstanding from the class the instructor then explains certain material in more detail.”
Allows students to self-assess or correct their misunderstanding	•	•		The FA helps students assess their own knowledge in order to realize whether they understand the material, or it helps them clarify or correct something they did not understand.	“its helped me know what I have a good understanding of and what I need to go back and review.” “It has helped clarify some things that I do not understand completely.”
Facilitates peer learning	•	•		The FA generates peer discussion or helps students learn from their peers.	“So that we can collaborate with other people to answer questions over the material. It’s to open us up to our peers’ ideas and understanding in order to aid with our own understanding.”
Promotes student ownership of learning	•	•		The FA helps students take control of their own learning process by learning on their own, teaching themselves, or constructing answers using their own knowledge.	“improved my ability to learn topics on my own” “They have allowed me to understand concepts better by explaining them in my own words”
Improves student learning	•			*Aggregate code: The FA is used to help students learn the material.	See examples for: Improves learning (generic) Encourages or changes thinking Encourages application or making connections
Improves learning (general)		•		The FA helps students learn, understand, visualize, or remember course material. This category also includes generic positive comments related to learning.	“It has really helped me learn the material and it has helped me understand it a little more.” “I am better able to picture what is happening and thus better comprehend what is happening as well.”
Encourages or changes thinking			•	The FA challenges students to think about the material, think more deeply/critically, or change their thinking (e.g., by focusing on the bigger picture or focusing less on memorization).	“Made me think more critically about biological processes.” “It makes me think of things on a larger scale rather than just memorizing out of a book.”
Encourages application or making connections			•	The FA helps students apply their knowledge (e.g., to real life contexts) or helps them understand how concepts/process are connected to one another.	“It has helped me apply the concepts we learn in lecture to real life situations.” “it helped me think on how the concepts fit together.”
Provides study tool for students	•	•		The FA provides examples, practice, sources for review, or serves as a study aid.	“provides more material to help me review before the test.” “To practice the skills learned in class.”

Improves attendance or in-class behaviors	•	•	The FA motivates students to attend class (or it allows the instructor to take attendance) or improves students' in-class behaviors (e.g., paying attention, taking notes, and engaging in class activities).	"It gets the students involved, allows the professors to monitor attendance." "It has motivated me to attend class." "It motivates me to pay more attention and take better notes."
Improves study habits or pre-class preparation	•	•	The FA leads to changes or improvements in student study habits (e.g., motivating reading, preventing procrastination), or it helps students prepare/become familiarized with the material before coming to class.	"They have taught me to read more in depth and take better notes over the chapter reading in the book." "have forced me to learn the material at a steady pace and not cram before tests." "So that we can learn the material before lecture, that way lecture material is not brand new and we can have questions prepared."
Benefits to students			*Aggregate code: Rather than mentioning influences on the instructor's teaching, the student mentions that the FA helps them learn the material, improve their own behaviors, or serves as a study tool.	See examples for: Improves learning (generic) Encourages or changes thinking Encourages application or making connections Improves attendance or in-class behaviors Improves study habits or pre-class preparation Provides study tool for students
Improves instructor's teaching or interactions	•		The FA is used to improve the instructor's teaching, (e.g., explanations, organization, etc.), provide an instructional tool (with specific mention of the instructor), or improve student-teacher interactions.	"To make lectures more interactive." "to give the professor a chance to give examples and explain them with direct student involvement." "To have a good communication between instructors and students."
Improves teaching or is a tool for teaching			The FA improves the instructor's teaching/explanations, is used by the instructor as a tool for teaching, or plays a substantial role in the instructor's teaching style.	"It has helped his teaching because it reinforces what he is talking about" "Used as review and to elaborate." "They have provided a structure for class." "He likes using them a lot and spends a good deal of class time discussing them."
Improves in-class interactions			The FA allows the instructor to interact with students or engage the students in class activities and discussions.	"Allows him to interact with students." "makes it easier to get such a big class involved." "They open up the floor for more discussion and more questions that might not otherwise be asked."
Changes pace or topics covered			The FA leads to changes in the pace of lecture or the amount of time/degree of depth spent on certain topics. These changes in content are due to reasons other than levels of student understanding (e.g., because topics were covered in the FA which frees class time for other topics).	"He doesn't have to focus on what is talked about in the book and can focus on helping us understand other concepts." "He has been able to skip over the basic teaching and talk about the concepts behind the material." "I guess since we are supposed to do it ahead of time, it helps him to be able to move quicker."
Aligns with lecture			The instructor addresses specific out-of-class FA questions in class, or the FA content is similar to the instructor's lecture topics (or vice versa).	"Allows the instructor to center their teaching around the subjects that the questions are based on." "Our professor goes over the answers to the homework quizzes and uses them as points of review in lecture."
Other purpose	•		The FA is used for some other purpose such as to increase grades, reduce stress, or for pacing/content management.	"They help cushion the grade in this class which is nice." "To break down the material the students need to know into smaller sections."
Unsure	•		The student is not sure why the FA is used in the course.	"I don't know"
Partial help		•	The FA is only a little helpful or only helpful sometimes.	"It has helped a little bit but not a ton." "It sometimes helps."
Unsure or no effect on teaching			The student does not know whether the FA influences the instructor's teaching, the FA does not affect the instructors teaching, or the instructor rarely or never uses/mentions the FA.	"I am not really sure." "It hasn't affected his teaching" "Not a lot because we don't discuss them much."
Negative (in response to why the FA is used)	•		Any negative comment or complaint about the FA or the instructor.	"some what unnecessary." "The clicker questions are very hard and not easy to understand." "Because the instructor doesn't understand how to properly teach course material."

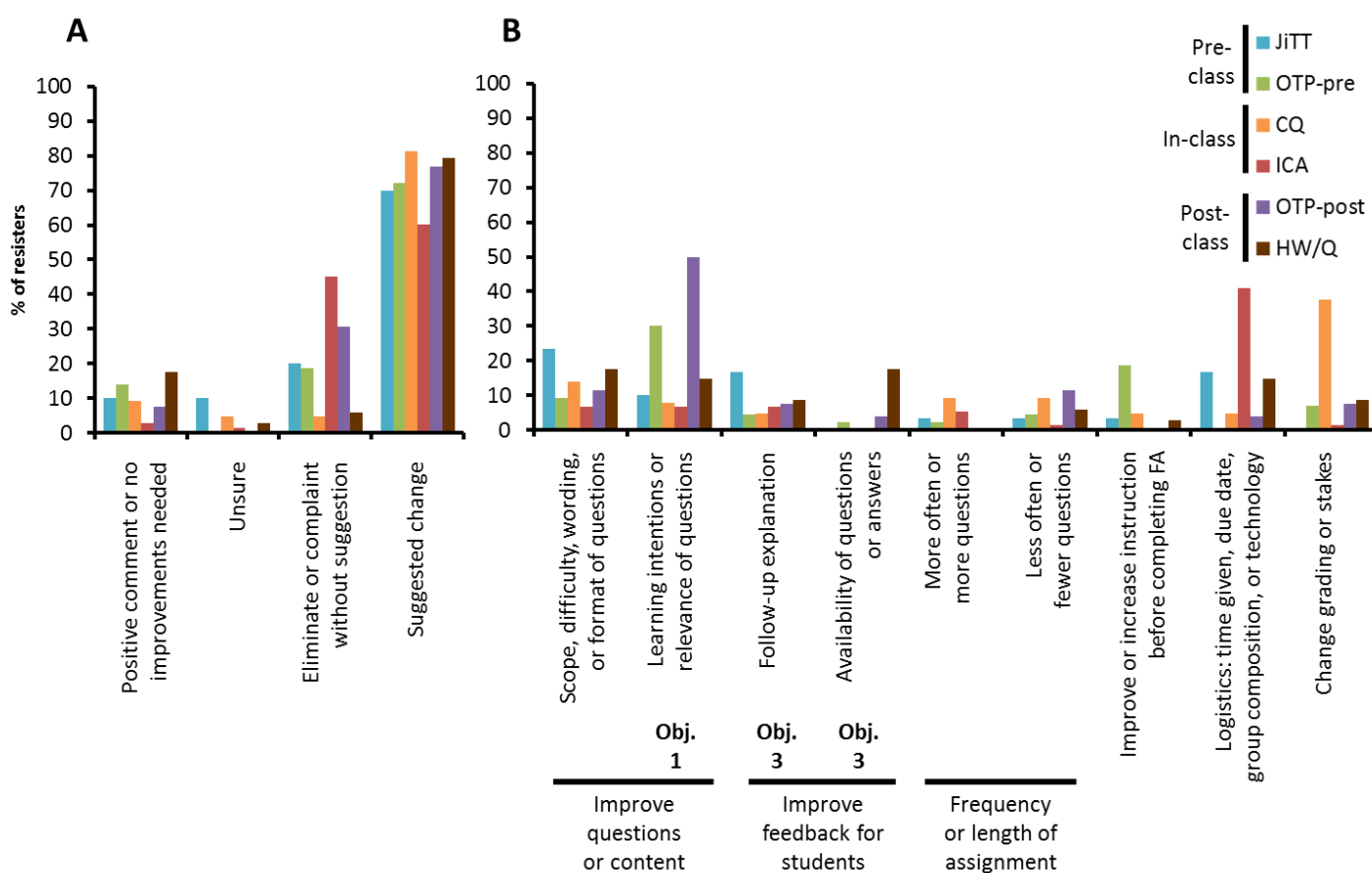
<i>Negative subcategories in response to how the FA influences learning:</i> General Specific  Hinders learning		•	A complaint about the FA without any explanation that is related to learning.	"I didn't really get anything out of it." "I hate that there is so much busy work in this course." "It has hurt my grade because i often forget we have homework quizzes due."
		•	A complaint that the FA does not help the student learn, along with an explanation/reason that is related to learning.	It probably has not helped.[...] A good portion of the questions diverge from what is essential to the learning objectives of the class." "not beneficial at all, it should be used to test our knowledge AFTER we've been taught the material. making us do them before is frustrating and does not help me learn anything"
		•	The FA is harmful to learning in some way.	"I feel like it has confused me more because the question aren't stated clearly."
<i>Negative subcategories in response to how the FA influences teaching:</i> Takes time away from lecture or teaching Instruction does not change based on feedback  Other complaint		•	The FA takes time away from when the instructor could be lecturing/teaching, or the material would be better taught/learned through lecture.	"I think that it would be more helpful if the professors just lecture and discussed the material we are learning." "It takes time that could be used lecturing."
		•	The instructor receives feedback about student understanding but does not change his/her instruction based on that information.	"If 4% of the class (such as in today's lecture) gets a question right, that should be a major red flag that the class is not understanding the material/the question. But this is never addressed and the lecture moves on as usual."
		•	A complaint about the professor's instruction (e.g., the instructor is not using the FA well) or about the FA itself.	"He just goes over the questions in class, but sometimes doesn't even show or give the answer directly. He starts talking about a lot of other things that lead to the answer and just confuses me more."

**Supplementary Table 2.** Definitions and sample student responses for each of the response categories for the open-ended question, “How might the use of [these FAs] be changed to improve your learning in this course?”

<b>Response category</b>	<b>Definition</b>	<b>Example quotations</b>
Positive comment or no improvements needed	The student gives a positive comment about the FA or a statement that it does not need to be changed.	“I thought the homework assignments all helped me in some way.” “I don't think they need to change they are very helpful with my learning in this course.”
Unsure	The student does not know how the FA could be improved.	“I don't know.”
Eliminate or complaint without suggestion	The student thinks FA should be removed from the course, or complains about the FA without including/implying a suggestion for how to improve it.	“Get rid of them.” “I can think of one occasion when the in-class activities were helpful, but for the most part I don't like them or find them useful.” “Not a fan of the team aspect of it!”
Scope, difficulty, wording, or format of questions	The scope, depth, difficulty, clarity of wording, or format of the FA questions or content should be changed/improved.	“More difficult questions that encourage critical thinking.” “focusing more on broader topics seems to be best.” “I think most of the times the wording of questions make it hard to understand what it is asking for.” “I would prefer that the quizzes be short answer.”
Learning intentions or relevance of questions	The questions or content of the FA should be more related to what the instructor expects students to learn, similar to exam questions, or relevant to topics being covered in the course or in the book.	“Questions that match the difficulty of the course and things we would see on an exam.” “more focused on what we should be learning.”
Follow-up explanation	The feedback following the FA should be improved to help students understand or clarify why the answers were right/wrong. This feedback can either come from the instructor or other resources.	“Talk more about the questions that we may not have understood.” “Just asking questions does not help. There should definately be very clear explanation for the answers to the questions.”
Availability of questions or answers	There should be access to FA questions or answers (e.g., the questions the student got right or wrong should be visible, the questions and/or examples of correct answers should be made available for later study, or there should be more attempts before the answer is revealed on an online assignment).	Clicker questions being posted online after class.” “Letting me see which questions I got wrong will help me decide where I should focus my attention.” “allow more attempts [...] if a student would try twice and get it wrong both times, there is no motivation for trying to figure out what the real answer is.”
More often or more questions	The FA should be used more often, or there should be more questions on activities/assignments.	“We only do it every once and while maybe make it a weekly thing.” “I would add more questions, covering more of the material.”
Less often or fewer questions	The FA should be used less frequently, less class time should be spent on it, or assignments should be shorter/take less time to complete.	“I think it would beneficial to keep clicker questions as part of the course, but fewer should be used per class because they take a large proportion of the time.” “Not as many questions.”
Improve or increase instruction before completing FA	More instruction or resources are needed prior to completing the FA, or the pre-class assignment should be moved to post-class.	“It would be helpful if we could go over the information in class first, then do the JITT questions.” “Better explanations of more specific material prior to completing the clicker question.”
<i>Logistics:</i> Time given or due date	The timing of the FA should be changed to allow for more time to complete the FA (e.g., by changing the due date or giving more time for in-class FAs), or the timing of in-class FAs should be changed within class (e.g., moving the FA to a different part of class or moving an in-class FA to outside of class.)	“More consistent due dates.” “I think quizzes could be changed by having them open for more than just the weekend.” “The instructors need to give the students more time for the in-class activities.” “Make sure to space questions so they fall at crucial times during a lecture.”
Group composition	The way that groups/teams are constructed or assigned should be changed.	“do it with the students we are sitting by. getting up and finding our group takes too much time and not everyone shows up ever.” “Pick our own groups because being assigned with other people, we don't really discuss the questions so I hardly ever learn from my team.” “Maybe occasionally switching up teams to hear different perspectives and ideas from different people.”
Technology, etc.	There are other logistical or technological issues with the FA that need to be addressed.	“I think the only issue with the clicker questions is that it usually takes the instructor a few minutes to get it set and working. If the teachers could be more fluent at setting it up we would save a lot of class time.”

Change grading or stakes	The grading scheme of the FA should be changed, either to be less strict/lower stakes or more strict/higher stakes grading.	“If the clicker questions were used for attendance only, I would be much less stressed about them and I would be able to calmly read and interpret the questions. Also, if I would get one wrong, I would be much less distracted afterwards because I would not be worrying about my grade in the class for the whole rest of the class time.” “Make them worth less overall points” “Make them worth more points so you can see an actual different in your grade.”
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“How might the use of [these FAs] be changed to improve your learning in this course?”



**Supplementary Figure 1.** Open-ended responses for “resisters” of each FA type about how FAs could be improved. Resisters were identified as students who disagreed or strongly disagreed that the FA was beneficial to them. X-axis shows all response categories for the open-ended question shown in the figure title. (A) Shows frequencies of overall themes of responses, and (B) shows the response categories comprising the “suggested change” theme. Bars show the overall percent of resisters whose response included each theme or category for the different FA types.