

Supplemental Material

CBE—Life Sciences Education

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SUPPLEMENTAL MATERIALS

Figure S1: Residual plots from final models

Figure S2: Ceiling Effect

Figure S3: Histogram of student responses

Table S1: Censored regression model results

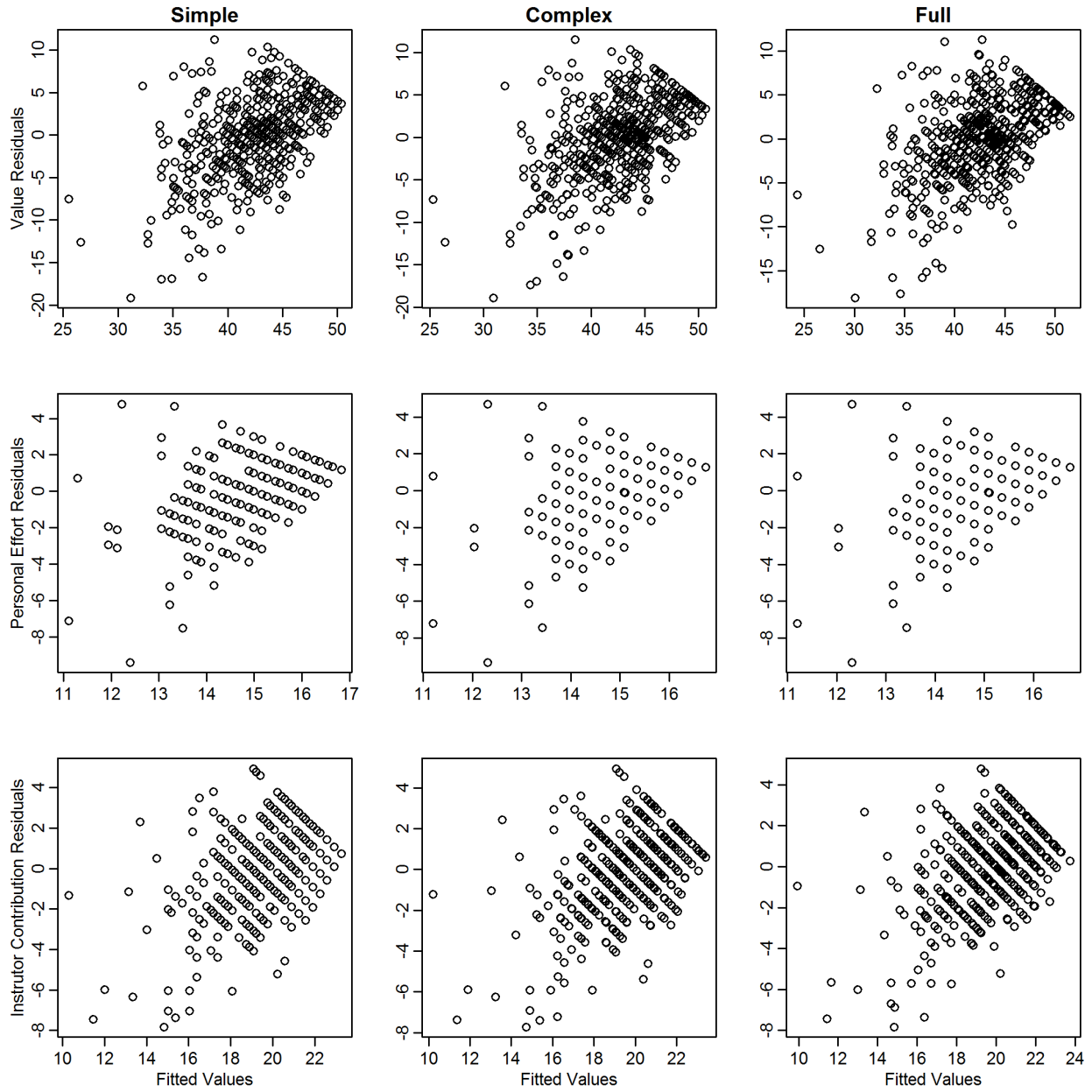
Table S2: Reliability and external validity of ASPECT: Cronbach's alpha coefficients

Document S1: Themes of student responses

Document S2: ASPECT final survey (16 items + 3 control questions)

Document S3: ASPECT long version of survey administered online (20 items + 3 control questions)

Figure S1: Residual plots from final models indicate that the residuals are not evenly distributed, rather, there is a strong ceiling effect.



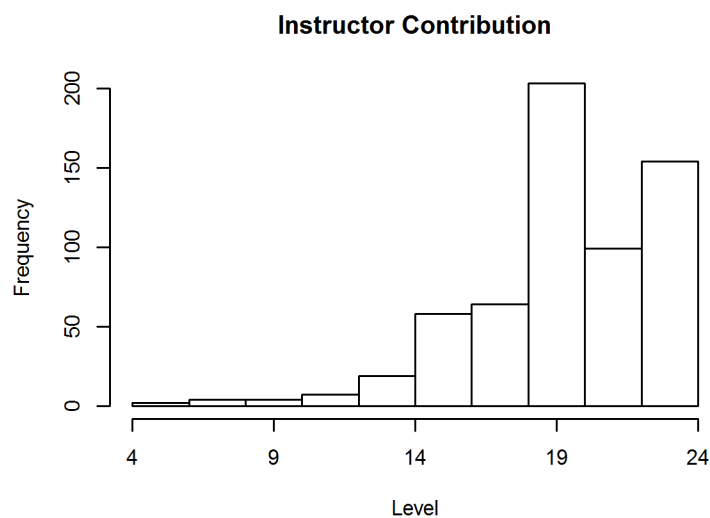
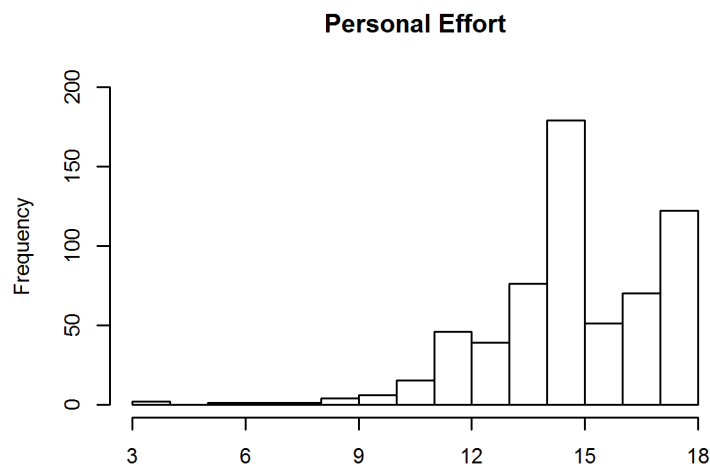
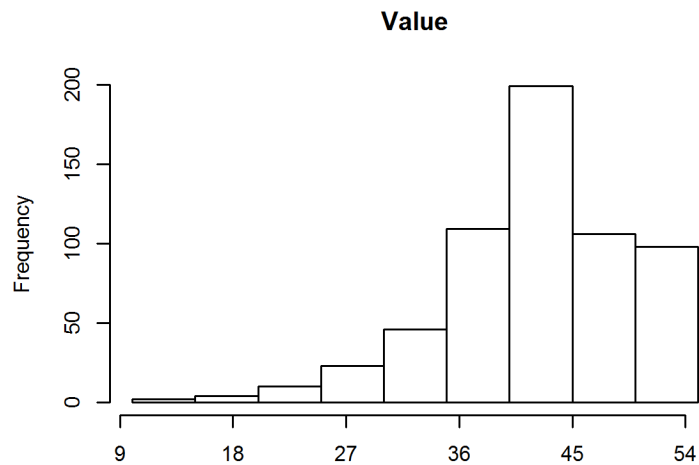
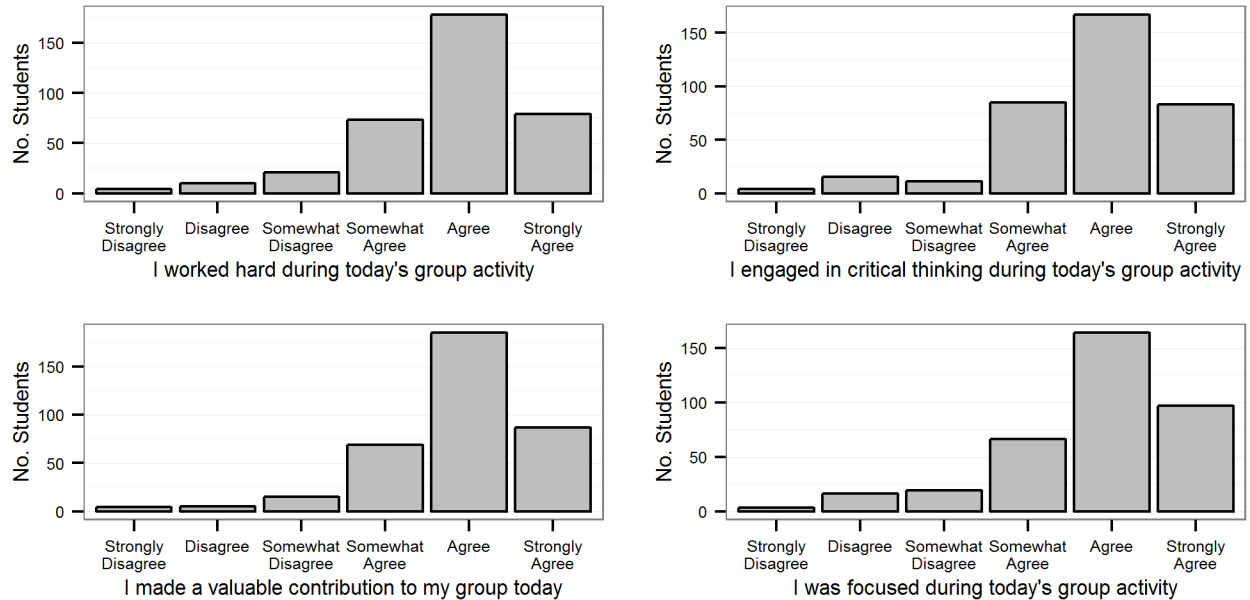


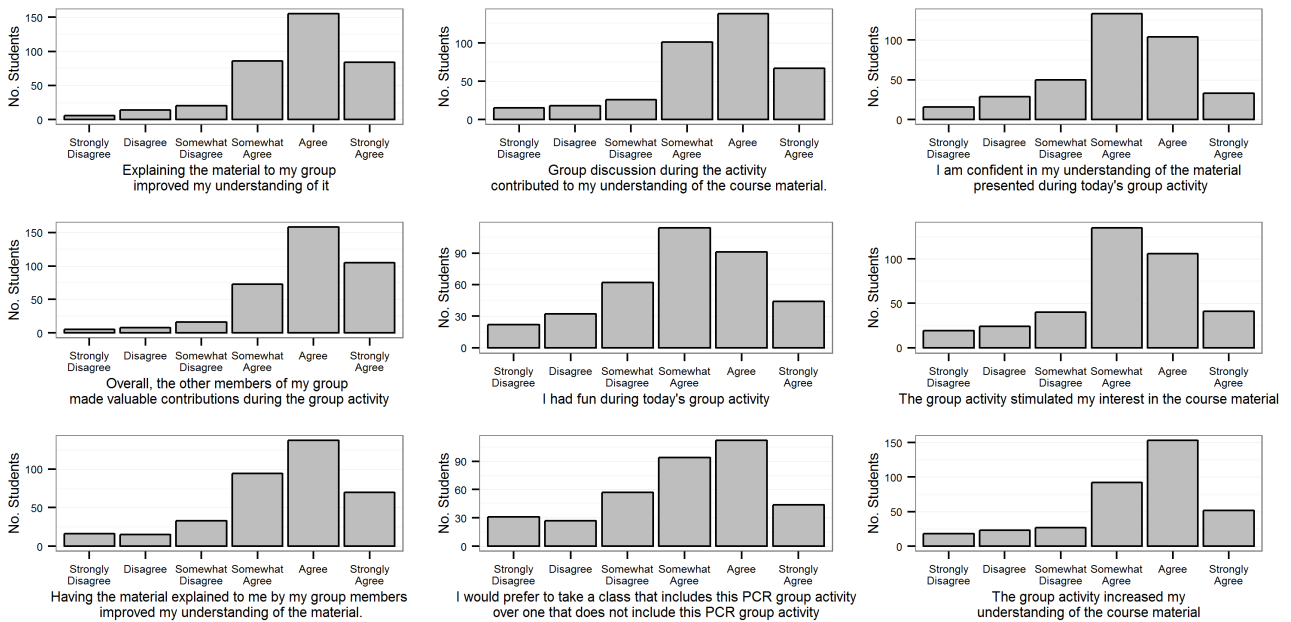
Figure S2: The ceiling effect in student responses is evident in the raw data – students tend to answer all questions favorably thus “max out” the scale of possible responses. In theory there could also be a floor effect wherein students are “not allowed” to answer below a certain value. However, student responses do not approach the floor thus the floor effect is not likely to influence inference. All levels shown are bounded between possible student responses.

Figure S3: Histograms of student responses on all ASPECT items. These histograms were used to assess if responses to any items were problematically narrow and lacking in distribution. Each set of diagrams corresponds to a single factor or to those three questions that did not load strongly onto any of the three factors.

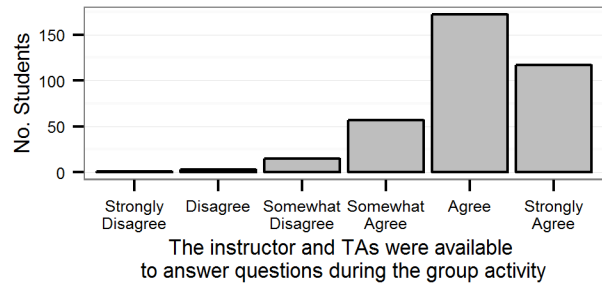
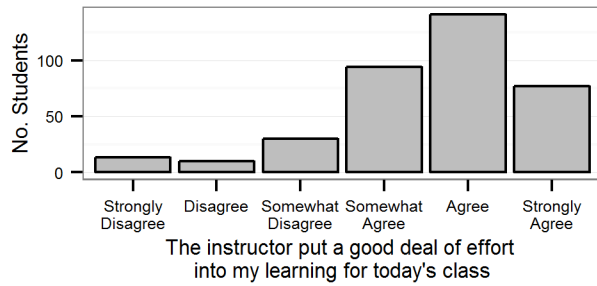
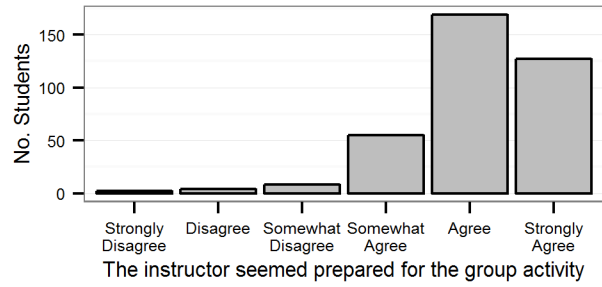
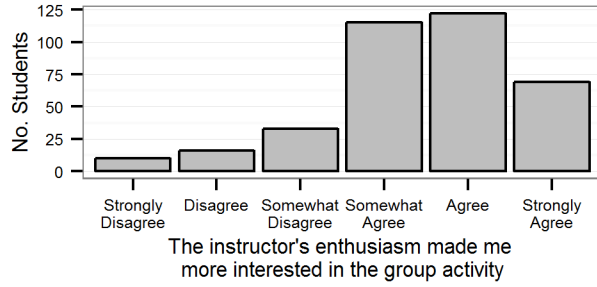
Items that loaded onto the Personal Effort factor:



Items that loaded onto the Value of Group Activity factor:



Items that loaded onto the Instructor Contribution factor:



Other three items that did not load well onto any of the three factors:

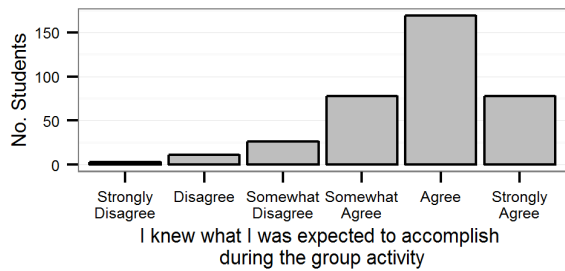
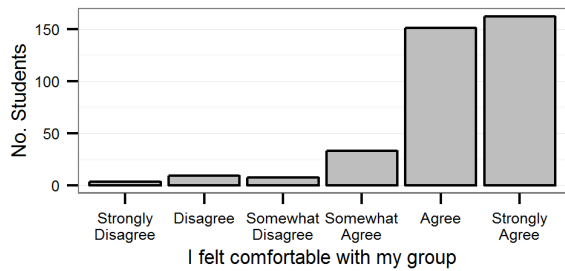
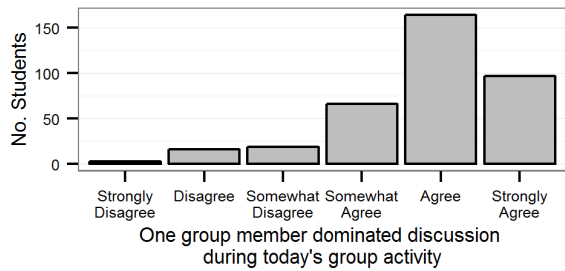


Table S1: Results from the censored regression models are qualitatively similar to the results from the linear mixed models thus either model type is appropriate for inference. The censored regression, however accounts for the ceiling effect thus are likely to be more accurate for precise estimation. Table shows relationship effect sizes from censored regression models, where students were specified as random effects. Grey cells indicate variables that were not included in the initial model; model selection procedure is described in Methods. Superscripts indicate reference groups and starting model, boldface coefficients indicate significance to $\alpha < 0.05$.

ASPECT Construct (outcome)	Intercept	Activity Type ¹	Ethnicity ²		Activity Type x Ethnicity	
Value ³	43.60	-1.06				
Value ⁴	42.64	-1.05	AA	2.04		
			Int.	1.00		
			URM	1.02		
Value ⁵	43.26	-2.26	AA	0.88	AA:Long	2.27
			Int.	-1.86	Int.:Long	5.77
			URM	1.51	URM:Long	-0.96
Personal Effort ³	15.37	0.22				
Personal Effort ⁴						
Personal Effort ⁵						
Instructor Contribution ³	21.05	-1.33				
Instructor Contribution ⁴	20.44	-1.33	AA	1.28		
			Int.	0.87		
			URM	0.45		
Instructor Contribution ⁵	20.60	-1.64	AA	0.94	AA:Long	0.65
			Int.	-0.10	Int.:Long	1.91
			URM	0.86	URM:Long	-0.79

¹Reference level: short activity.

²Reference level: white; AA stands for Asian American, Int. stands for International, URM stands for Under Represented Minority.

³Simple model was specified as Outcome ~ Treatment + (student random effect).

⁴Complex model was specified as Outcome ~ Treatment + Demographics + (student random effect). Student demographics included university GPA, Ethnicity, First Generation Status, and Gender.

⁵Full model was specified as Outcome ~ Treatment + Demographics + Treatment*Demographics + (student random effect). Student demographics included university GPA, Ethnicity, First Generation Status, and Gender.

Table S2: Comparison of Cronbach’s alpha values resulting from exploratory factor analysis of student responses to ASPECT administered to different populations

Factor	Fall 2014^a	Winter 2015	Winter 2015
	Long Activity Day^c	Long Activity Day	Short Activity Day^d
Value of Group Activity	0.91 ^b	0.91	0.91
Personal Effort	0.84	0.81	0.78
Instructor Contribution	0.78	0.84	0.82

^aQuarter of introductory biology course to which the survey was administered
^bCronbach’s alpha values
^cLong activity day refers to a class day in which students completed a ~30 minute worksheet followed by instructor feedback
^dShort activity day refers to a class day in which students completed 8-10 “clicker-question” activities centered around instructor-posed clicker questions

Document S1: Themes in large-scale validation of responses to ASPECT items

Factor 1: Activity's influence on learning

Explaining the material to my group improved my understanding of it:

N= 37

Themes:

- Dominant theme: explaining allows them to check their understanding (*'I think by explaining the material, not only you are able to have a better understanding of it but your group members can also help point out if what you are saying is right or wrong'*)
- Some vague answers indicating that students may not be referencing the activity specifically but be considering the general value they see in explaining (*'I'm am the kind of learner that likes to talk out my thoughts in order to solidify them. Thus explaining concepts to my group helped fortify them in my head'*)

Having the material explained to me by my group members improved my understanding of the material:

N = 40

Themes:

- Deciding whether or not listening helped them learn (*'the discussion helped clear up questions or confusions I had about the processes and they could explain it in ways aside from the text that was understandable'* or *'in certain cases as a group member explained something to me, they did not know exactly what they were talking about or were completely wrong'*)
 - This was influenced primarily by
 - Whether or not they trusted their groupmates
 - Whether or not they were comfortable with groupmates
 -

Group discussion during the [topic] activity contributed to my understanding of the course material:

N = 38

Themes:

- Improved understanding because discussing topic (*'it's easier to understand a concept and get a full picture of it when you discuss it with others'*)
 - This was primarily because:
 - Multiple perspectives heard
 - Someone in group was knowledgeable
- Over half referenced how peer's contribution influenced their understanding

I had fun during today's [topic] activity:

N = 33

Themes:

- Many students referenced fun as enjoying learning (*'the [activity was] fun because the group can work at their own pace and there is an interactive element involved'*)
- A few talked about fun like it was enjoyable (*'I completed it with a friend and it was fun'*)
 - Having a friend in the group or not influenced fun (*'I really have no social connections to anyone in the class and I tend to feel like I'm bothering a group of friends who would rather not have me latched on when we're expected to work in groups'*)
 - Lack of confidence in ability to learn from activity limited fun (*'my confidence in the material was not strong, therefore, it made the [activity] more frustrating than fun'*)

Overall, the other members of my group made valuable contributions during the [topic] activity.

N = 38

Themes:

- Need knowledge to valuably contribute to group (*'members in my group had read and were able to contribute helpful information'*)
- Participation is considered a valuable contribution (*'my other group member was actively participating and helping to answer the questions just as much as I was'*)
- 2-3 people said hearing different perspectives from group members was a valuable contribution (*'discussing the questions with group members was helpful since everyone in the group had a different way of thinking about the material'*)
- Value was always in reference to the participant not value to the group

I would prefer to take a class that includes this [topic] activity over one that does not include this activity:

N = 29

Themes:

- Frequently referenced this type of long in-class activity in general (*'I don't learn very well through the [long class] activities. I'd much rather just listen to a lecture and take notes' or 'having the visual aids on the paper to refer to really helps me solidify my understanding of what is going on'*)
- Gave reasons why they did or did not like the long in-class activities (many different explanations)
- Activity features limited preference (*'today's activity was entirely too long unless you somehow knew every answer right away'*)

I am confident in my understanding of the material presented during today's [topic] activity.

N = 35

Themes:

- Explained how well they did or did not understand the material for the day (*'I actually sometimes, am more confused if the exact correct answer is not presented straight away'*)
- Confidence limited by lack of preparation on their part or procedural problems (*'I was not fully prepared when coming into class today. However, having a group discussion helped clarify any confusion on the matter'*)

The [topic] activity increased my understanding of the course material:

N = 49

Themes:

- Described how activity helped them learn (*'the group activity was helpful because it allowed me to discuss concepts with my classmates and get a chance to teach as well. It also helped me figure out what parts of the material I was not confident in'*)
- Procedural problems (like bad wording on questions) could limit learning
- Many students compared to their preference for lecture (*'I personally like getting information through a lecture style and then applying the information in a group setting'*)

The [topic] activity stimulated my interest in the course material:

N = 33

Themes:

- How activity stimulated interest: primarily working with others was what engaged them with material (*'talking with the group engaged me with the subject, thus making it more interesting'*)
- Lack of understanding limited ability to be stimulated

Factor 2: Personal Effort

I made a valuable contribution to my group today:

N = 33

Themes:

- Valuable contribution is giving correct information (*'I helped explain concepts regarding [topic] to my partner who did not know about these topics'*)
- Small number said that their contribution was limited by their confusion (*'once I started to understand the topic, I was able to contribute to the group and help them understand'*)

I was focused during today's [topic] activity:

N = 39

Themes:

- Personally engaged (*'I was engaged in discussion with my group members about the [activity]'*)
 - Primarily influenced by:
 - Structure of activity (*'if I had my own worksheet I think I would be able to pay attention more'*)
 - Difficulty level and how interesting activity was influenced focus (*'[topic] is still a little 'iffy' to wrap my head around, so today I made it my goal to stay focused and work on improving my understanding of the topic'*)
 - Relevance of activity (*'I was focused during today's group activity since this will make me understand the PCR concepts better and this will help for studying my final'*)
 - Outside of class events (like a holiday)(*'being the Monday after break I can't admit I was at 100% focus today'*)

I worked hard during today's [topic] activity:

N = 39

Themes:

- Explained whether or not worked hard with:
 - Whether or not contributed to group (*'I felt like I was an active participant during the group activity today'*)
 - Whether or not trying to learn/interested (*'I really enjoyed this [activity], and because of that, I worked hard'*)
 - Whether or not their group functioned well (*'it was frustrating today because I really wanted to work on the worksheet but nobody seemed interested'*)
 - Staying focused (*'I found it easy to be distracted given the setting in the large lecture hall'*)

Factor 3: Instructor Contribution

The instructor's enthusiasm made me more interested in the [topic] activity:

N = 35

Themes:

- Instructor's enthusiasm made students value activity (*[our instructor] is engaging with her teaching style and this [activity] in particular was helpful...*)
- About half referenced instructor's effort generally (*'[our instructor] makes all her classes enjoyable because you can tell she really enjoys the subject'*)

The instructor put a good deal of effort into my learning for today's class:

N = 0

Note: this item inadvertently did not go through the large-scale face validation step.

The instructor seemed prepared for the [topic] activity:

N = 45

Themes:

- Prepared seemed to be determined:
 - Primarily by instructor's ability to respond to questions in class (*'She never seemed confused and could explain each aspect of the topic in depth'*)
 - Secondly by prepared with materials ready (*'[our instructor] had worksheets ready for everyone, and had clicker questions to test our progress and understanding'*)
- ~1/3 gave general responses (*'[our instructor] is always prepared'*)

The instructor and TAs were available to answer questions during the [topic] activity:

N = 42

Theme:

- Mostly referencing if instructor/TA available when needed help (*'when i raised my hand to ask a question, either a TA or the instructor immediately came to help'*)

Items below were removed after EFA analysis due to poor inter-item correlation or weak/no loading on factors

One group member dominated discussion during today's [topic] activity.

N=34

Themes:

- group equity (*'everyone contributed to the discussion'*)
 - Influenced primarily by
 - personal approach (*'I tend to dominate discussions a bit'*)
 - valuing each other's contributions (*'there were people that talked a little bit more but we all helped each other answer the questions'*)
 - structure of activity (1 sheet per group)(*'The group member with the paper did most of the reading and writing and would therefore begin (sic) discussion by giving her thoughts'*)
 - having a friend in the group (*'we were all friends and valued each others answers'*)

I knew what I was expected to accomplish during the [topic] activity

N=33

Themes:

- clarity of questions and instructions on activity (*'the directions are pretty clear on the worksheet'*)
- clarity of instructor's verbal instructions/feedback (*'[our instructor] kept us updated about which questions we would be expected to complete in a certain time frame'*)
- relevance of activity for their learning (*'I knew that [the activity] would help me have a better understanding about [topic x] for the test'*)

I felt comfortable with my group.

N= 37

Themes:

- Ability to share ideas freely (*'they would not care if I said a wrong answer'*)
- Familiarity with group members (*'I knew my group members'*)
- Group members were all engaged/interested (*'some members would rush others with the goal to finish it rather than stop, ask questions, and discuss'*)
 - influenced primarily by:
 - whether or not had a friend in the group (*'all of my group members were my friends'*)
 - general friendliness of groupmates (*'everybody was nice'*)
 - size of group (*'I get to ask questions in a smaller group instead of the whole class'*)
 - personal attributes (*'I am typically a pretty outgoing and easy to talk to person' or 'I'm scared of people, human interaction, and just talking in general'*)

I engaged in critical thinking during today's [topic] activity*:

N = 29

Themes:

- Students had a wide variety of definitions of critical thinking including:
 - applying prior knowledge (*'I thought back to different course materials in order to fully answer the activity questions'*)
 - teaching themselves (*'we were able to use smaller questions to guide a thought process that allowed us to come to the solutions ourselves'*)
 - navigating a challenging activity (*'a lot of it was confusing, so that's why I said I engaged in critical thinking'*)
 - overcoming external problems (*'it's harder for me to focus when it's louder in [the lecture] hall'*)

*This item was removed from the final ASPECT due to ambiguous interpretations of the term "critical thinking"

Document S2: ASPECT (Final 16-item survey)

Note: In our administration of the survey, we inserted the name of the specific activity students completed in that day's class (e.g. eukaryotic gene regulation activity) in order to remind students of the activity to which the survey is referring. It may be possible to generalize the survey to refer to "group activity".

Instructions for students:

All questions in this survey refer to today's class in which you completed an activity on *[insert topic name]*. Your responses on this survey will be used to evaluate how we teach this topic in future Biology classes. Your instructor will not know whether you completed this survey or how you answered the questions, but your effort will impact the experience of future students in this series.

Setup questions – to be used to control for student group experience

A) During class today, you and your classmates completed a *[insert topic name]* activity in a group. How many students (including you) worked in your group?

Possible Answers: 1 (just me)
 2
 3
 4
 More than 4

B) Are you friends with at least one person that was in your group?

Possible Answers: Yes
 No

C) As a college student, have you been asked to work with other students during class time in large lecture courses (over 100 students)? Do not include this class in your answer.

Possible Answers: Yes
 No, other large lecture courses I have taken have not asked me to do this
 No, this is the first large lecture course I have taken

For questions 1-16, students answered on a 6-point Likert Scale from Strongly Disagree to Strongly Agree.

Instructions for students

The following questions ask you about your experience with the [insert topic name] activity that you completed today. Please rate how strongly you agree or disagree with each of the following statements.

- 1) Explaining the material to my group improved my understanding of it*
- 2) The instructor's enthusiasm made me more interested in the *[insert topic name]* activity
- 3) Having the material explained to me by my group members improved my understanding of the material**
- 4) Group discussion during the *[insert topic name]* activity contributed to my understanding of the course material
- 5) The instructor put a good deal of effort into my learning for today's class.
- 6) I had fun during today's *[insert topic name]* activity.

- 7) Overall, the other members of my group made valuable contributions during the *[insert topic name]* activity.
- 8) The instructor seemed prepared for the *[insert topic name]* activity.
- 9) I would prefer to take a class that includes this PCR group activity over one that does not include this *[insert topic name]* group activity.
- 10) I am confident in my understanding of the material presented during today's *[insert topic name]* activity.
- 11) I made a valuable contribution to my group today.
- 12) The instructor and TAs were available to answer questions during the *[insert topic name]* activity.
- 13) The *[insert topic name]* activity increased my understanding of the course material.
- 14) I was focused during today's *[insert topic name]* activity.
- 15) The *[insert topic name]* activity stimulated my interest in the course material.
- 16) I worked hard during today's *[insert topic name]* activity.

* Included an extra answer choice: "I did not explain material to my group today"

** Included an extra answer choice: "A group member did not explain the material to me"

Document S3: ASPECT (long version piloted in our study)

For questions 1-20, students answered on a 6-point Likert Scale from Strongly Disagree to Strongly Agree

Instructions for students

The following questions ask you about your experience with the [topic name] activity that you completed today. Please rate how strongly you agree or disagree with each of the following statements.

- 1) Explaining the material to my group improved my understanding of it. *
- 2) The instructor's enthusiasm made me more interested in the group activity.
- 3) Having the material explained to me by my group members improved my understanding of the material. **
- 4) Group discussion during the activity contributed to my understanding of the course material.
- 5) The instructor put a good deal of effort into my learning for today's class.
- 6) I had fun during today's group activity.
- 7) Overall, the other members of my group made valuable contributions during the group activity.
- 8) The instructor seemed prepared for the group activity.
- 9) I would prefer to take a class that includes this PCR group activity over one that does not include this [topic] activity.
- 10) I am confident in my understanding of the material presented during today's group activity.
- 11) I made a valuable contribution to my group today.
- 12) The instructor and TAs were available to answer questions during the group activity.
- 13) The group activity increased my understanding of the course material.
- 14) I was focused during today's group activity.
- 15) The group activity stimulated my interest in the course material.
- 16) I worked hard during today's group activity.
- 17) I felt comfortable with my group.***
- 18) I knew what I was expected to accomplish during the group activity.***
- 19) One group member dominated discussion during today's group activity.***
- 20) I engaged in critical thinking during today's [topic] activity.****

* Included an extra answer choice: "I did not explain material to my group today"

** Included an extra answer choice: "A group member did not explain the material to me"

***Removed from final EFA due to weak loading onto factors

****Removed from final version due to ambiguous wording