# Perceptions of Active Learning between Faculty and Undergraduates: Differing Views among Departments

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## Abstract

There have been numerous calls recently to increase the use of active learning in university science, technology, engineering, and math (STEM) classrooms to more actively engage students and enhance student learning. However, few studies have investigated faculty and student perceptions regarding the effectiveness of active learning or the barriers to its implementation. Previous work surveying a single class in a single department has suggested that faculty and students have different perceptions of the effectiveness of active learning strategies and the barriers faculty face when implementing these teaching strategies. We expand on these previous findings by surveying a larger and more diverse sample of students and faculty in a college consisting of five departments. We find that students and faculty agree that active learning techniques are useful, effective, and should be implemented more widely, but disagree on the percentage of class time currently devoted to active learning. When we parsed the data by department, more nuanced perceptions became apparent. The perceived barriers to implementing teaching reform differed in importance by department and in some departments relatively few faculty had observed or used active learning. Our findings suggest that advocates of teaching reform must recognize that not all departments or institutions face the same barriers to implementing curricular changes.

*Keywords:* Active learning, undergraduate, faculty, professional development, education reform

## Introduction

As a part of teaching reforms called for by numerous scientific organizations (e.g., Handelsman, Miller, & Pfund, 2007; Kober & Council, 2015), scientific teaching practices, including active learning, have been implemented in higher education STEM programs across the country (e.g., Andrews, Leonard, Colgrove, & Kalinowski, 2011; Freeman et al., 2014). Active learning techniques increase student success and engagement in the classroom using a variety of activities including group discussions, clicker questions, debates, and projects (Freeman, et al., 2014). Numerous studies have demonstrated the effectiveness of these techniques, particularly for first-generation and minority college students (Eddy & Hogan, 2014; Freeman, et al., 2014; Freeman, Haak, & Wenderoth, 2011; Wood, 2009). Despite positive student perceptions and evidence of the efficacy of active learning, many faculty members do not implement these strategies in their classrooms (Ebert-May et al., 2011; Miller & Metz, 2014). Our study allows us to use empirical data to gain an understanding of how both faculty and students perceive various teaching methods to help identify which teaching methods are being used, attitudes towards these methods, barriers to implementing various methods, and how these barriers might be reduced. Our study is also crucial to the conceptual underpinnings of science education research because without such data from individual institutions to inform models of change, it is doubtful that wide-spread instructional transformation can occur within an institution, within a discipline, or within STEM.

Previous work to understand faculty and student perceptions of teaching methods have shown that students often feel that they learn more when active learning is employed, but they do not necessarily like the activities themselves (e.g., Machemer & Crawford, 2007; C. V. Smith & Cardaciotto, 2012). Faculty tend to recognize that active learning benefits students but cite myriad barriers to changing their own teaching styles, including lack of (or perceived lack of) preparation time, class time, classroom control, and administrative support (e.g., Michael, 2007; Silverthorn , Thorn, & Svinicki, 2006). Differences in expectations and limited communication between faculty members and education researchers have also been shown to be barriers to implementing more student-centered teaching practices (Henderson & Dancy, 2007, 2008). Others have suggested that professional identity, specifically the perception that being viewed as a teacher confers lower status than being viewed as a researcher, may also present a barrier to pedagogical change that must be lowered for these practices to be widely implemented (Brownell & Tanner, 2012).

Expanding this work, Miller and Metz (2014) surveyed 119 first-year dental students and nine faculty members in a physiology department to investigate student and faculty perceptions of the effectiveness and use of active learning techniques in the classroom and perceived barriers to its implementation. They found that these professional-level students had very positive perceptions of the effectiveness of active learning and suggested that 40% of class time should be devoted to active learning. The student perceived barriers to its implementation included faculty not seeing this technique as useful, being accustomed to lecturing, and lack of training in the method. On the contrary, professors did indeed perceive active learning methods positively, but perceived lack of class time, being accustomed to lecture, and lack of time to develop materials as their biggest barriers to implementing active learning. Investigating student perceptions of active learning is important in its own right; asking students what barriers to implementation they think faculty face is enlightening and could help faculty gain perspective on what their students think of them and their teaching style.

Exploring how student and faculty perceptions differ among disciplines can lead to better insights with which to guide professional development programs for both groups. Faculty use of student-centered teaching techniques has been shown to differ within the sciences. For example, a national survey of geosciences faculty found that while many faculty still lecture, a large proportion included some type active learning in their classrooms (Macdonald, Manduca, Mogk, & Tewksbury, 2005). A similar national study of physics faculty indicates that 88% of faculty were aware of research-based instructional strategies, but only 49% currently used one or more strategies in their classrooms (Henderson, Dancy, & Niewiadomska-Bugaj, 2012). Other work surveying all STEM courses within a university suggests that instead of a dichotomy between strictly lecture faculty and strictly active learning faculty, there is a continuum with these extremes at the opposite ends of the spectrum (M. K. Smith, Vinson, Smith, Lewin, & Stetzer, 2014). These results suggest that further exploring perceptions and implementation differences among disciplines, even within a university, is necessary to better understand how to increase active learning in the classroom. In this study, we expand upon the work of Miller and Metz (2014) by gathering similar data for a much larger and more diverse population of faculty and students.

The Louisiana State University (LSU) College of Science is made up of five departments, including the Department of Biological Sciences. This department has hosted faculty professional development workshops (STAR and the National Academies Gulf Coast Summer Institute) for 8 years covering scientific teaching strategies, including active learning (Handelsman, et al., 2007). Thirty-two faculty and instructors and two graduate students in the College of Science have participated in these trainings, mostly from the Department of Biological Sciences. While this would suggest that many science courses, particularly biology classes, are taught by instructors who have at least been exposed to these techniques, we were unsure of how many courses actively engage students, how active learning in general was perceived by the faculty, or what possible barriers might be limiting the implementation of these practices in the College of Science. In addition, we were unaware if faculty perceptions of teaching methods differed by department or if they were similar across the board; this information will be crucial when providing effective professional development programs or reducing the barriers to implementation. Similarly, a large proportion of undergraduates in the College have likely been exposed to active learning techniques in at least some of their classes, but we don't know how many classes, student perceptions of the effectiveness of the techniques, or what students perceived as barriers to implementation of active learning by faculty.

Thus, our research goals are 1) better understand faculty and student perceptions and use of active learning teaching techniques and barriers to its implementation across the College of Science and 2) determine if these perceptions differ among the departments within the College. To address these gaps in our knowledge, we sent surveys modeled after Miller and Metz (2014) to all faculty and undergraduates in the College of Science at LSU.

## Methods

### Institution

Louisiana State University (LSU) is a public, RU/VH (Research University, Very High research activity), Land-, Sea-, and Space-Grant University. The College of Science consists of five departments: the Department of Biological Sciences (including the Museum of Natural Science), the Department of Chemistry, the Department of Geology and Geophysics, the Department of Mathematics, and the Department of Physics and Astronomy (hereafter referred to as biology, chemistry, geology, mathematics, and physics, respectively). There were approximately 246 faculty and 2436 undergraduates in the College when the survey was implemented during the Fall 2014 semester.

### Study Participants

Undergraduate participants were identified as any student seeking to major in a bachelor's degree program within the College of Science. A link to the survey was sent to all students fitting this criterion. Faculty participants were identified as all tenure- and non-tenure-track faculty and instructors in any department in the College of Science. The link to the survey instrument was sent to all members of the College of Science faculty listserv managed by the Dean's office.

### Survey instruments

The faculty and undergraduate survey instruments closely resemble those used by Miller and Metz (2014). Some questions were removed or modified slightly to make the instrument more applicable to LSU. Miller and Metz's (2014) definition of active learning was displayed at the beginning of the survey for all participants:

Active learning is an instructional method in which students become engaged participants in the classroom. Students are responsible for their own learning through the use of in-class: written exercises, games, problem sets, i-clickers, debates, class discussions, etc.

In addition, since recent research has suggested there might be differences in the usefulness of active learning for different groups of students, we asked the undergraduates to self identify their race/ethnicity, gender, and if they were first-generation college students. We did not ask faculty for demographic information because we did not want to be able to potentially identify survey participants. The project and all survey instruments were approved by LSU's IRB, project #E9078. All survey instruments are available in the online supplementary materials. These materials are available from the authors.

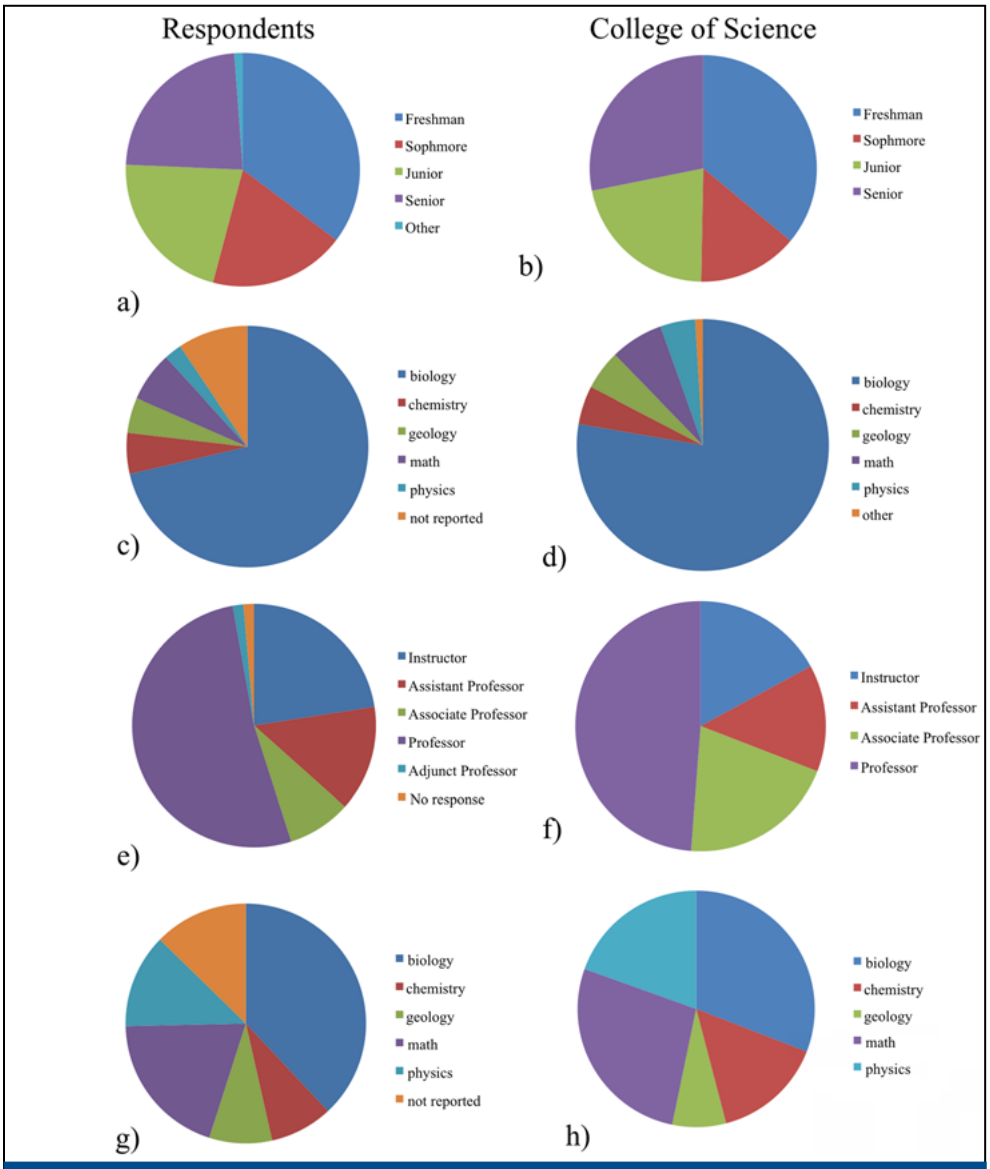



**Figure 1. Graphical breakdown of survey participants. a) Proportion of undergraduate respondents to the survey by academic year. b) Proportion of undergraduates in the College of Science by academic year. c) Proportion of undergraduate respondents to the survey by department hosting their reported major. d) Proportion of undergraduates in each department in the College of Science. e) Proportion of faculty respondents to the survey by position level. f) Proportion of faculty in each position in the College of Science. g) Proportion of faculty respondents to the survey by department. h) Proportion of faculty in each department in the College of Science.**

### Statistical analyses

All analyses were implemented in R (R Development Core Team, 2013). We used the Mann-Whitney U-test to investigate differences between undergraduate and faculty opinions and use of active learning activities. Comparisons of paired student or faculty data were assessed using the Wilcoxen Signed-Rank Test. The Kruskal-Wallis test was used to investigate differences in student or faculty perceptions among departments. If this test indicated significant differences among departments, the nparcomp package (Konietschke, Placzek, Schaarschmidt, & Hothorn, 2014) was used to determine which departments were driving significant differences.

## Results

### Number of participants

A total of 255 undergraduate students completed the survey, representing approximately 10.5% of the undergraduate students in the College of Science. Participants were relatively evenly distributed among class years with slightly more freshmen responding (Figure 1a). The majority of respondents reported majors that fell within the Department of Biological Sciences (Figure 1c); this is representative of the composition of students in the College of Science (Figures 1b and d). Most students who responded were white (72%) and more females (67%) completed the survey than males (31%). Students had taken an average of 3.8±4.2 classes (range: 0-30 classes) that used active learning in the classroom.

Seventy-one faculty members completed the survey representing 29% of the faculty in the College. Just over half of these responses (52%) were from full professors (Figure 1e) with the largest proportion of faculty from the Department of Biological Sciences (Figure 1g). The responses from faculty by rank and department were roughly representative of the overall composition of faculty in the College (Figures 1f and h). These faculty had an average of 17.5 ±12 years (range: 0-45 years) of teaching experience and teach an average of 1.4 ± 0.8 classes (range: 0.5-4 classes) each semester.

### Faculty versus undergraduate responses to questions

Nearly 80% of the faculty who responded had observed and used active learning in their classrooms (Figure 2a), and most had found it effective (Figure 2b). Students and faculty agreed that active learning improved long-term retention of information, exam scores, overall learning, and motivation to learn, and students found active learning enjoyable (Figure S1). Students and faculty also agreed that more active learning should be happening in classrooms (termed "Best practice" by the authors in the figures below) but disagreed as to how much is currently occurring (Figure 3).

The teaching methods that students perceived as most effective were often significantly different from those that faculty used most often or perceived as most effective (Figure 4). Both students and faculty identified significant differences between current frequency of use and efficacy of educational games, group learning, lecture, and problem solving (Figure 4). Students and faculty disagreed on the effectiveness of educational games, videos, and group learning; students perceived the former two activities as more effective than the faculty, while students perceived group learning as less effective than did faculty (Figure 4a). There were significant differences in the types of activities faculty were currently using and those they perceive they should be using (termed "Best practice" by the authors): faculty feel they should be using problem solving, group learning, and games significantly more often and lecturing significantly less often (Figure 4b).

The single biggest perceived barrier to implementing active learning according to faculty who haven't used the technique is that there is not enough class time (Figure 5). This perceived barrier was also identified by students and faculty already using active learning (Figure 5). However, these latter groups, which were remarkably similar in their perceptions of the importance of individual barriers, also identified not enough time to develop materials, having become accustomed to lecture, and that active learning is not a productive use of class time as barriers to implementation encountered by faculty (Figure 5).

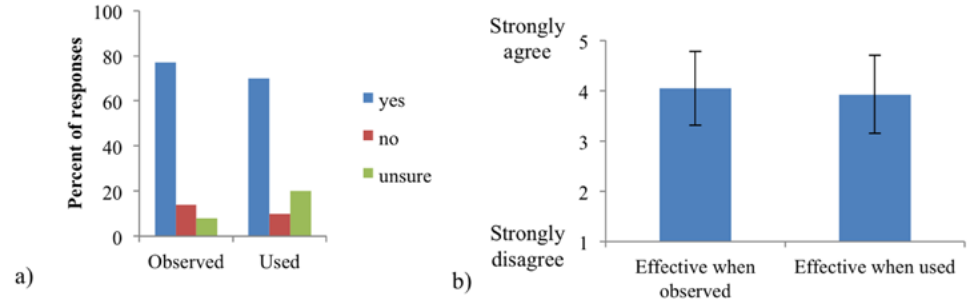



**Figure 2: a) Percent of faculty members who have observed or used active learning in their classrooms. b) Faculty perceptions (mean ± SD) of the effectiveness of active learning when observed and used.**

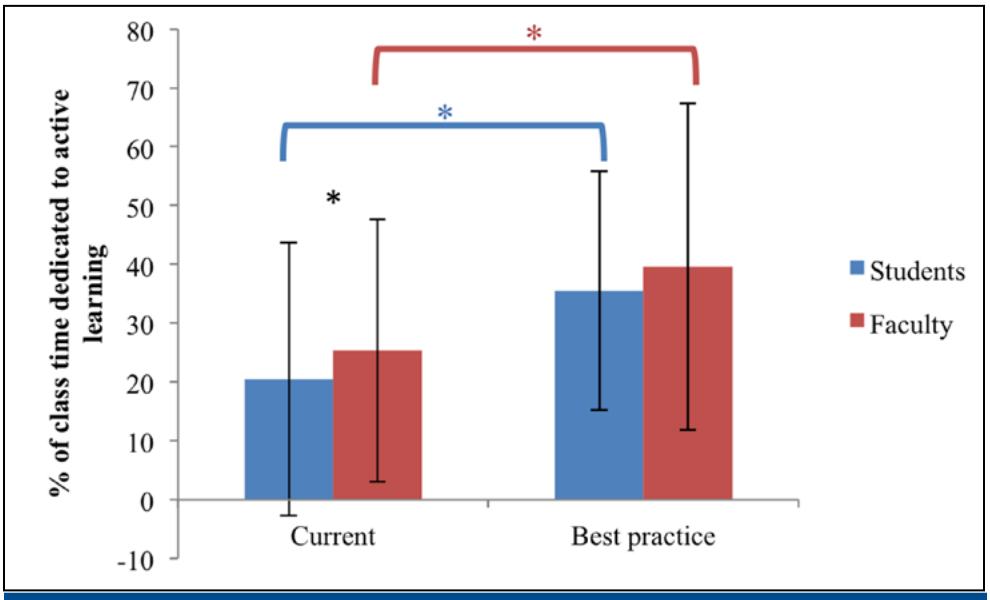



**Figure 3: Student and faculty perceptions of the amount of class time currently devoted to active learning and how much time should be devoted (Best practice) to active learning. Data shown are mean percent class time ± SD. *= P < 0.05 between faculty and student perceptions (Mann-Whitney U-test) and within student and faculty perceptions (Wilcoxen Signed-Rank test).**

### Faculty versus undergraduate responses by department

Over 80% of the faculty respondents in every department had observed active learning except the Department of Mathematics in which only 40% of faculty reported observing active learning in the classroom (Figure 6a). At least 80% of the faculty from biological sciences, chemistry, and geology had used active learning in the classroom while fewer than 70% of the faculty from mathematics or physics had used active learning (Figure 6b). It is important to reiterate that the faculty self-reported their use of these strategies, which may not accurately reflect their true classroom practices (Ebert-May, et al., 2011). Despite these differences in use/observation there were no significant differences among departments in how effective active learning was when observed or used; all faculty had

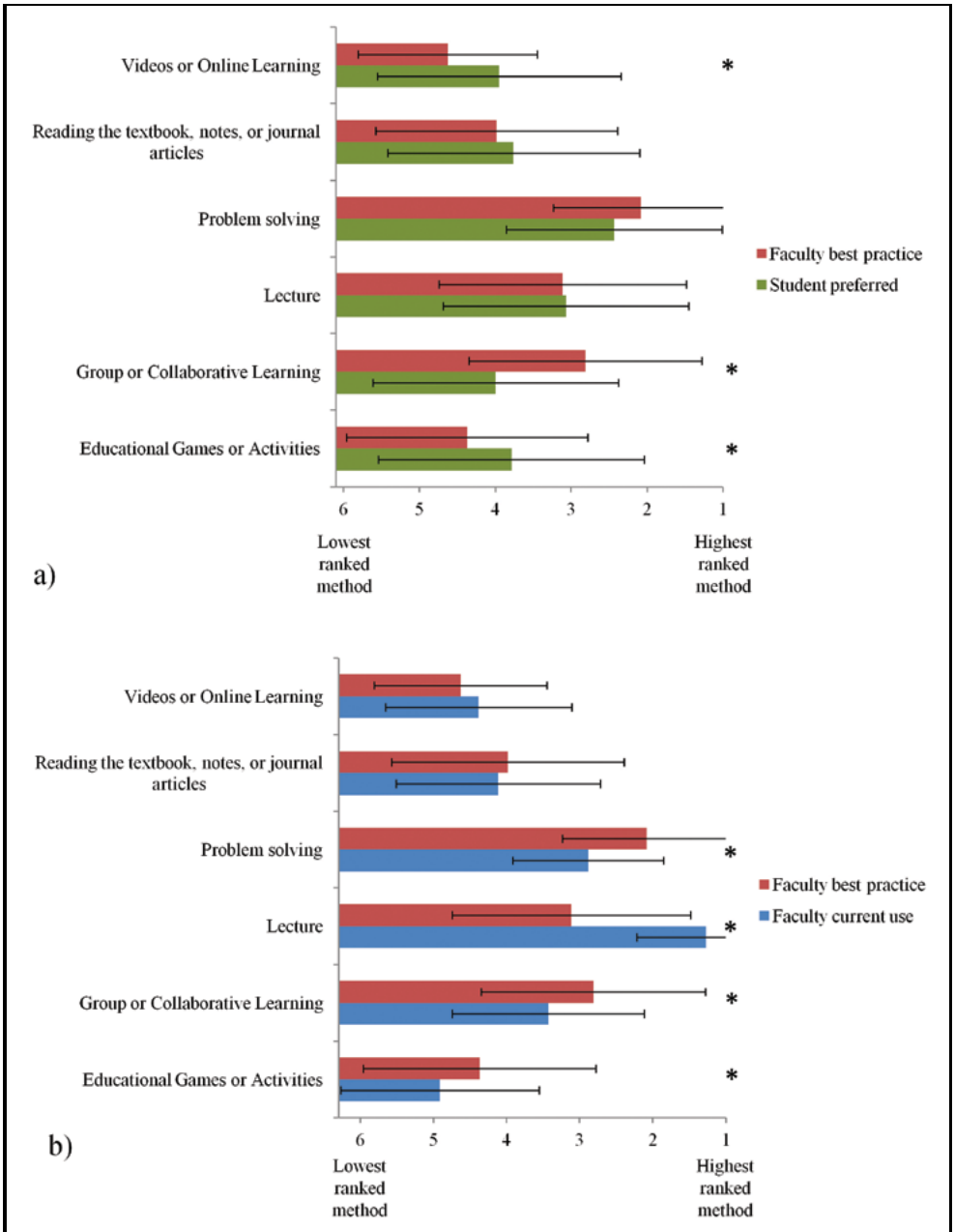



**Figure 4: Comparison of teaching methods a) considered by faculty to be most effective (Faculty best practice) and considered by undergraduates to be most effective (Student preferred) and b) most frequently used by faculty (Faculty current use) and Faculty best practice. Data shown are mean ± SD. * P< 0.05 between datasets based on the Mann-Whitney U-test or Wilcoxen Signed-Rank test.**

positive perceptions of its effectiveness (Figure 6c). Every department had faculty respondents who participated in some type of course or curriculum development or education research (Figure S2). There were no significant differences among departments for either students or faculty in their perception of active learning techniques on various aspects of learning including student enjoyment, performance on exams, and long-term retention of information (Figure S3 a and b). Overall, students and faculty from all departments perceived active learning techniques as having a positive effect on various aspects of learning (Figure S3 a and b).

Students from different departments report significant differences in the percent of class time currently devoted to active learning, with students from biology, geology, and math driving these differences, whereas there was no significant difference in the amount of time faculty from different departments reported currently using active learning (Figure 7). Interestingly, faculty and students from the same department agreed on the amount of time currently spent on active learning (with the exception of geology) and the amount of time that should be spent on active learning (with the exception of chemistry; Figure 7).

In nearly every case, there were no significant differences in the most preferred or the most effective teaching method for students or faculty among departments (Figure S4). There was a significant difference among departments in how often faculty currently used problem solving in the classroom: biology faculty used problem solving significantly less than physics faculty and geology faculty used it significantly less than math and physics faculty (Figure S4b).

Overall, there was little departmental variation in the student-perceived barriers preventing faculty from implementing active learning techniques (Figure 8a), although there were a few exceptions that stood out. For example, over 90% of chemistry and geology undergraduate respondents thought that faculty had "become accustomed to lecture-based methods" while only about 65% of math and physics students thought this was the case (Figure 8a). In addition, only 20% of physics majors perceived class size as a barrier to active learning while at least 40% of students from other majors thought this was a barrier (Figure 8a). When faculty perceived barriers were broken down by department, several interesting trends emerged. A much larger percentage of chemistry faculty members perceived class size, administrative support, and other factors not listed as barriers to implementing active learning than did faculty from other departments (Figure 8b). Biology faculty perceived becoming accustomed to lecture as more of a barrier than other faculty (Figure 8b). Finally, active learning was not perceived as a useful tool or use of class time for a larger percentage of physics faculty members than those from other departments (Figure 8b).

## Discussion

Our results suggest that faculty and students in the College of Science at LSU, who perceive active learning as effective, also think that it should be used more often than it currently is in the classroom, and revealed that there were large departmental differences in how often it was implemented. Compared to Miller and Metz (2014), our results tend to have lower means and/or larger standard deviations for the questions pertaining to the effectiveness of active learning, the amount of class time that should be devoted to active learning, and fewer LSU faculty had observed or used active learning. We suggest two possible, not mutually exclusive explanations for these differences. First, our sample was much larger and more diverse in terms of student composition and departments than that of Miller and Metz (2014); this alone could account for the large variance in our data. Second, Miller and Metz (2014) knew exactly what kinds of experiences with active learning their students had since Miller herself had implemented all of the active learning sessions in the class they surveyed. The number of classes taken and taught that implemented active learning varied widely in our sample and we have no way of standardizing their experiences based on the quality of active learning. This is illustrated in the 149 comments students wrote in response to the optional question "Please describe your experience with active learning in the classroom." While most of these comments were positive, several students stated that ac-

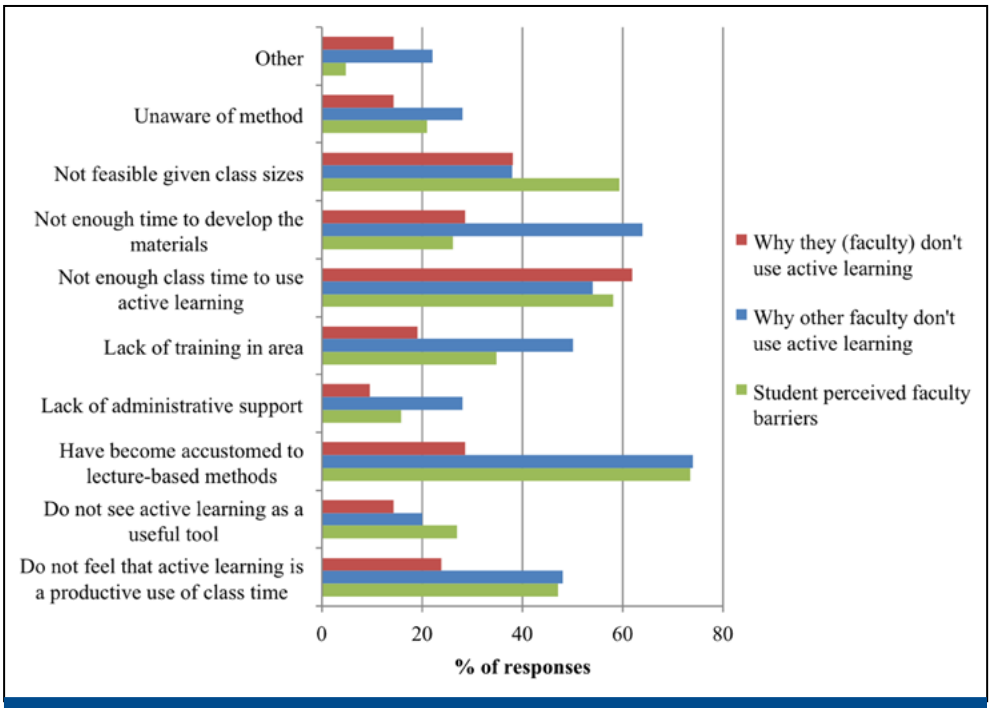



**Figure 5: Perceived barriers to implementing active learning in the classroom.**

tive learning in their classrooms was not implemented in a consistent, organized, or useful manner. This perception is supported by recent work suggesting that active learning does not increase student learning when it is used by faculty members who have not been trained in its implementation (Andrews, et al., 2011); while we did not collect data on whether faculty in our sample had attended any professional development training in teaching methods, we suspect that many had not. These caveats aside, our data allow us to probe deeper into faculty and student perceptions of active learning to make recommendations for lowering the barriers to its implementation.

## Faculty versus student perceptions

Faculty and undergraduates agreed that active learning techniques were useful and effective (Figures 2 and S1) and should be used more than they are currently (Figure 3). Students perceived that less time is currently spent on active learning than did faculty. While it is possible that the students and faculty responding to our survey had never shared time in the same classroom, our results indicate that faculty overestimate the time they currently

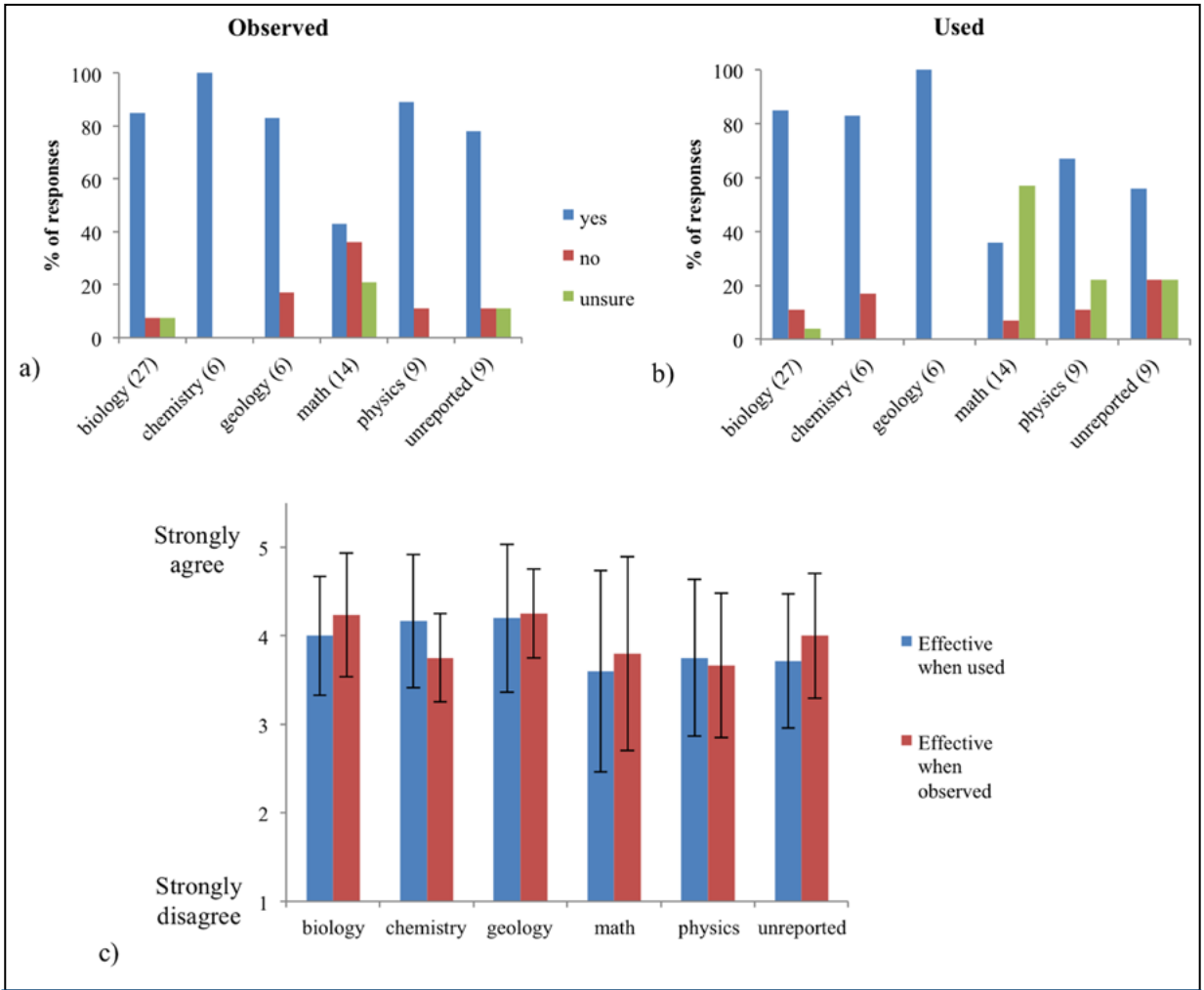



**Figure 6:** a) Percent of faculty members by department who have observed active learning. b) Percent of faculty members by department who have used active learning in their classrooms. c) Faculty perceptions (mean ± SD) by department of the effectiveness of active learning when observed and used. There were no significant differences in faculty perceptions among departments based on the Kruskal-Wallis test.

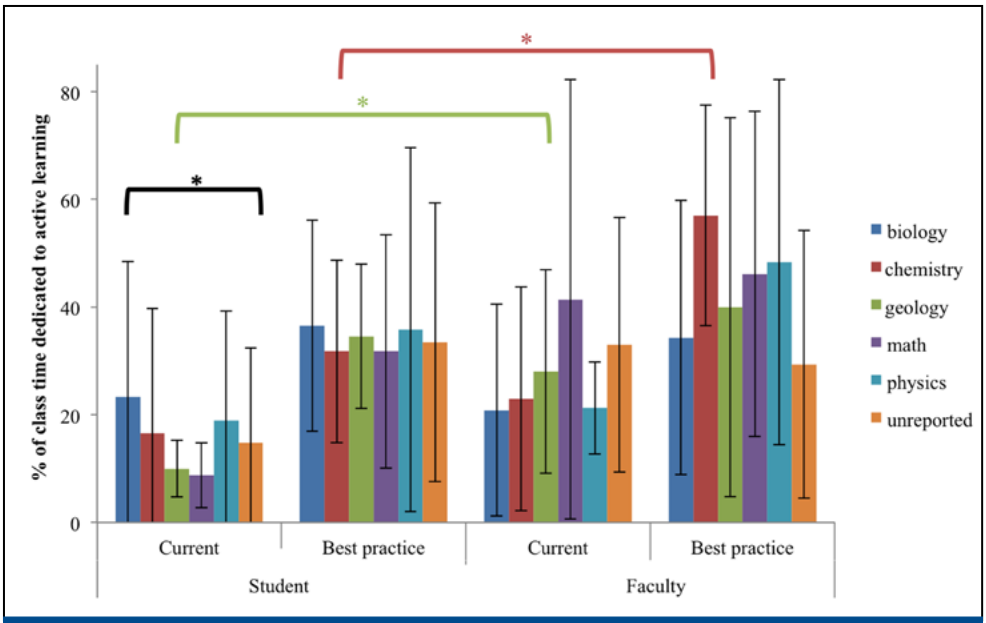



**Figure 7: Student and faculty perceptions of the amount of class time currently devoted to active learning and how much time should be devoted (Best practice) to active learning by department. Data shown are mean percent class time ± SD. *= P < 0.05 between departments for student's perceptions of amount of class time currently devoted to active learning. Perceptions of geology and math students differed significantly from those of biology students at P<0.05. The green bracket indicates a significant difference (p=0.01) between geology students and faculty in perception of time currently spent on active learning. The burgundy bracket indicates a significant difference (p=0.03) between chemistry students and faculty in time that should be devoted to active learning. All other comparisons among departments were not significant (Kruskal-Wallis test).**

spend actively engaging students in the classroom and/or students underestimate this time. Previous work has shown that most faculty consistently overestimate the amount of time they spend on active learning (Ebert-May, et al., 2011); we are unaware of studies addressing the possibility that students underestimate the time faculty spend on active learning. Asking students and faculty to complete time budgets for courses they are taking or teaching would be an interesting exercise to more fully explore this question.

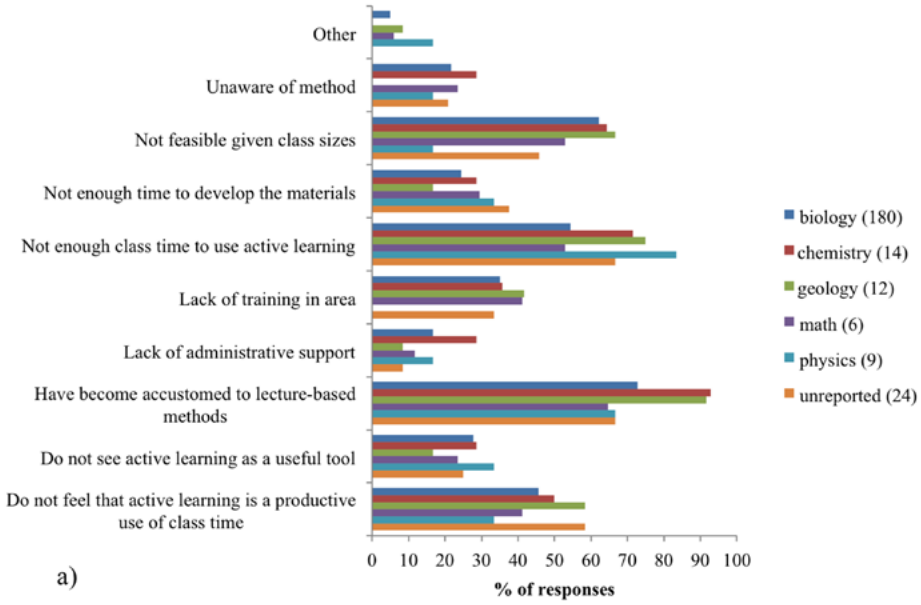
In our study faculty and students agreed that approximately 40% of class time should be devoted to active learning techniques, similar to the findings of Miller and Metz (2014) and only 5% of our surveyed students indicated that less than 5% of class time should be devoted to active learning (data not shown). This indicates that most students in our sample were ready and willing to participate actively in the classroom. Indeed many students will enthusiastically participate in active learning as evidenced by comments students wrote at the end of the survey including gems such as: "A formal study is unnecessary to prove the effects of active learning. It is much easier to grasp concepts by doing. [. . .] However, in my opinion, the BEST professors are those that can couple active learning with lecture based presentations. [. . .] I am literally so sick of attending STALE ass lectures." This is contrary to concerns expressed by some faculty respondents; when asked if they had additional comments about active learning, several faculty respondents stated that there is or would be a lack of student buy-in when active learning is incorporated into the classroom. However, the fact that most faculty perceived they should be doing significantly more active learning in class suggests that they recognize the utility of these techniques in increasing student interest, engagement, and learning but have logistical concerns regarding how to successfully do so. When asked to rank teaching methods, clear trends arose (Figures 4 and S4) but there was substantial variation (evidenced by large standard deviation bars) within students and faculty; this indicates that there is a continuum along which active learning is implemented similar to Smith et al.'s findings (2014).

Faculty already using active learning (50 respondents) and students perceived similar barriers for other faculty to implement active learning, including not enough time to develop materials or use them in class, not a productive use of time, and faculty being accustomed to lecture (Figure 5). This suggests to us that students have a better understanding of these issues than some might give them credit for. In addition, we think it is valuable for faculty to see what students perceive as barriers to implementing active learning strategies. Students (11 respondents) also suggested that "Other" barriers to implementation included varying degrees laziness on the part of the faculty, that students might not fully participate, and that faculty members don't care about student success. Faculty already using active learning methods suggested that "Other" barriers (10 respondents) included lack of ready-made active teaching modules, auditorium-style classrooms, expensive technology, student dissatisfaction, and lack of interest in being a good teacher. None of these "Other" barriers were identified by faculty respondents not currently using active learning as keeping them from implementing these techniques. In fact, the single largest perceived barrier to implementing active learning for faculty that had not used it before (21 respondents) was lack of class time (Figure 5): it was the only suggested barrier identified by more than 50% of these faculty. These results are similar to those of Miller and Metz (2014) who found that lack of class time was a barrier for 89% of the faculty in their study. The few "Other" responses from these faculty in our study (3 respondents) included necessity of institutional change for teaching reform to be effective. The disparity in the perceived barriers to implementing active learning among the different groups is notable; this illustrates that care should be taken when advocating for and implementing teaching reforms.

## Perceptions of active learning vary by department

Perhaps the most notable result in the present study becomes clear when we break down responses by department. In mathematics, far fewer faculty had observed (43%) or used (36%) active learning techniques (Figure 6). Furthermore, while most physics faculty had observed active learning (89%), only 67% had used active learning in the classroom (Figure 6). These results are rather startling compared to the other departments in the College in which 83-100% of the respondents had observed and used active learning (Figure 6). Many more math faculty were unsure of whether they had observed or used active learning, perhaps suggesting that the definition of active learning we provided (see Methods) may have been unclear to them.

Our inter-departmental results are similar to those from previous studies. A recent national survey of physics professors found that only 49% regularly used "ready-made research-based instructional strategies" (Henderson, et al., 2012). An older nation-wide survey of geosciences faculty members indicated that while nearly all of the respondents lectured, at least 60% of them incorporated some active learning techniques (e.g., "Lecture/entire class answers"; Macdonald, et al., 2005). There are key differences between the surveys from these previous studies, for example, the physics survey did not include questions about the use of more general active learning strategies or activities designed and used by individual professors, so this number may not reflect the actual amount of student-centered learning occurring in physics classrooms while the geosciences survey included only general activities. However, the trends highlighted in these studies underline the fact that the differences among de-



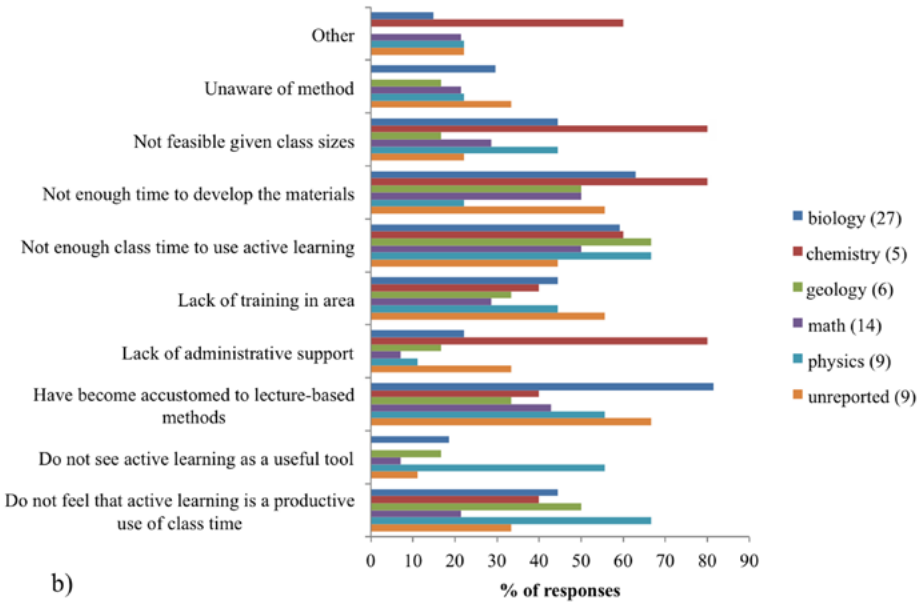




**Figure 8: Perceived barriers to implementing active learning in the classroom for a) students and b) faculty by department. Sample sizes are in parentheses.**

partments we observed at LSU are also reflected in other datasets. Overall, these results indicate that a broad, one-size-fits-all approach to faculty development should not be used across institutions, or even departments within institutions, because we cannot assume that the barriers and incentives necessary to achieving institutional or even departmental change will be uniform across institutions or disciplines.

Despite departmental differences in the observation and use of active learning, faculty from all departments agreed that active learning was effective and useful (Figures 6 and S3), as did students from different departments (Figure S3). This at least shows that there is some common ground among departments and survey participants in their attitudes toward active learning which can be used as a foundation from which to build professional development and student success programs.

While the amount of perceived class time currently devoted to active learning differed significantly among students with different majors, overall they agreed on how much class time should be devoted to active learning (Figure 7). It is possible that our results could be skewed by the large number of respondents majoring in biology. However, this level of agreement is perhaps not surprising as we asked students to assess active learning in classes they had taken within the College, which for most science majors, including biology majors, would encompass the majority of the classes they are required to take. There is much less agreement (although no statistical differences) among faculty from different departments in how much active learning they perceive they were currently implementing or should be implementing (Figure 7). This is likely a reflection of the departmental differences in observation and use of the techniques described above, but still serves to highlight the fact that overall, the faculty perceive active learning as useful and that they should be implementing it more often.

Student identified barriers do not differ substantially by department (Figure 8a), suggesting that students view faculty as a rather homogeneous group regardless of department (despite the exceptions noted above), similar to how they perceive class time within the College. When we look at faculty perceived barriers by department, we find that there are some striking differences (Figure 8b). For example, only chemistry faculty members perceived lack of administrative support as an important barrier. Similarly, a larger proportion of physics faculty perceived that active learning is not a useful tool and not a productive use of class time than did faculty from other departments. These results highlight the importance of tailoring incentives to implementing active learning and programs to lower barriers to implementation to individual departments; the perceived barriers in one department may be trivial in another.

## Recommendations for lowering the barriers to implementation

Many authors have already made extensive recommendations to lower implementation barriers and improve professional development (PD) programs (e.g., Brownell & Tanner, 2012; D'Avanzo, 2013; Henderson, Beach, & Finkelstein, 2011; Henderson & Dancy, 2007, 2008; M. K. Smith, et al., 2014). Our results reinforce these recommendations but we would like to highlight several suggestions that we feel are particularly important given our findings. While these recommendations are by no means exhaustive, we do think that they should be applicable across multiple institutions.

-It is critical for the department or institution to "know itself" before change can occur (Henderson, et al., 2011; Miller & Metz, 2014; M. K. Smith, et al., 2014). Surveys or focus groups exploring faculty perceptions of teaching techniques and implementation barriers are a crucial first step before enacting a PD plan. Administrators of PD programs should not assume that faculty in all departments have the same level of exposure to or attitudes toward active learning techniques. In the current study this is evidenced by the low percentage of math faculty that had observed or used active learning. This suggests that finding a way for these professors to observe active learning in action (perhaps by having other faculty members invite them to observe their student-centered classes) before suggesting training on how to implement it may be a crucial first step to introducing, and hopefully generating an interest in, more learner-centered teaching methods.

-Faculty in some departments, such as physics, had observed active learning but had not yet used these methods in their classes. This suggests that these faculty members are ready for training sessions in using and implementing active learning techniques. These training sessions should cover ways to facilitate group discussions and projects; include discipline- specific examples of, and best practices in using, a variety of activities; and guidance in creating their own activities.

-PD in active learning should focus on ways faculty can incorporate active learning into their courses without sacrificing course content and how this switch can be done gradually to minimize the time commitment involved in developing activities. This is particularly important as faculty in our study and others (e.g., Miller & Metz, 2014; Silverthorn , et al., 2006) have perceived this as a significant barrier. Helping faculty gradually add more student-centered activities allows them to "get their feet wet" and become comfortable using alternatives to lecture without becoming overwhelmed with the idea of switching all of their classes all at once. Our suggestion would be for "new converts" to focus on a single class at a time and incorporate one new activity per week. If this continues for several semesters/quarters, that faculty member will have made great strides in converting their course, will have a repertoire of activities, and should then be ready to begin converting another course. Self-reflection on how the activities went and how they might be improved is also crucial.

-After PD, faculty should be encouraged to form and maintain teaching and learning communities within and between departments where they can collaboratively create and test teaching activities and discuss teaching issues should they arise (Silverthorn , et al., 2006). While several faculty mentioned in their comments that they want more pre-made activities, previous research has suggested that many instructors don't use such materials for a variety of reasons (Henderson, et al., 2011; Henderson & Dancy, 2007, 2008; Silverthorn , et al., 2006).

-The barriers preventing implementation of active learning cannot be assumed to be the same among departments; only by identifying these differences can specific efforts be made to lower these barriers. If efforts are not made by individual faculty members, department chairs, deans, and other university administrators to lower these barriers, widespread acceptance and use of active learning methods will be severely hindered.

-Finally, we suggest that students need to be prepared to actively learn in the classroom to increase their buy-in and participation. First, the concept of active learning should be introduced during freshman orientation so students have exposure to why they will be expected to actively engage in their classes and suggestions on how they might do so. Second, instructors should make their expectations of students clear, and preferably employ some activities on the first day of class, so students understand how to meet these expectations. Third, student learning or tutoring centers should offer training sessions or tutoring on how to fully participate in their classes so they can make the most of these active learning techniques to increase their overall learning. In particular, these trainings should help students to become more effective members of a group as well as make students aware that the ability to work in a group is a skill that is highly valued by employers (NACE, 2014).

### Limitations of the survey instrument and study design

We modified the instruments developed by Miller and Metz (2014) only slightly, in order to make our results directly comparable to theirs. We feel that using the same or similar survey instruments across institutions and studies can increase the usefulness of the resulting data by making it easier to compare results among departments and institutions, thereby facilitating interpretation of the data. However, researchers who use this instrument in the future might consider the following caveats.

-Throughout the instruments "lecture" is used when "class period" may be more appropriate. In LSU's College of Science, the non-laboratory portions of courses are routinely referred to as the "lecture" portion, so we feel that the term "lecture" was justified for the present study, but researchers at other institutions may need to modify this terminology.

-As mentioned in the introduction, some departments, particularly biological sciences, offer teaching workshops or journal clubs; in addition some faculty members may have had other teaching training at some point in their careers. Based on the percentage of faculty members participating in various aspects of curriculum and course design and development (Fig. S2), we suspect that at least some of our respondents had participated in teaching professional development, though we have no way of knowing how many, or if these trainings changed faculty perceptions of active learning. We suggest adding such questions to the survey in the future.

-We did not offer survey respondents any incentives or rewards for their responses. The department chairs and the Dean of the College of Science were made aware of the survey via emails and/or in-person meetings but to our knowledge did not encourage their faculty or students to participate. Incentives for participation, such as being entered into a drawing, may have increased the number of respondents and should be considered by future researchers. We are unsure if encouragement by administrators would likewise have increased participation. Based on research suggesting that providing incentives for students to complete course evaluations increased student respondents but did not change the overall evaluation scores (Donmeyer, et al., 2004), we suspect that our results would only be strengthened by increasing our sample size.

-The "Teaching Methods" categories are very broad and could encompass several teaching techniques and several specific engagement pedagogies were not specifically listed. For example, the single "Educational Games and Activities" category could be split into at least two separate categories one consisting of "Educational Games" and the other "Educational Activities", each of which could be further subdivided. Our "Problem Solving" category could encompass individual, group, or whole-class activities as well as specific pedagogies such as problem-based learning or peer-led team learning (i.e., Eberlein et al., 2008). We deliberately left these categories broad because we had little idea what types of active learning techniques faculty in other departments were already familiar with or the connotations, good or bad, associated with specific activities in different disciplines. Other researchers may want to amend the list of activities in the future.

## Conclusions

By surveying faculty and undergraduates in LSU's College of Science, we have a better understanding of how these groups perceive active learning and the barriers to its implementation, and how often active learning is currently implemented in science classes. Although overall students and faculty perceive active learning as a useful technique, we found that these perceptions were quite heterogeneous across departments, with some departments utilizing active learning more than others, based both on student and faculty perspectives. Administrators often suggest that incentivizing the switch to active learning will lead to more widespread acceptance and implementation. However, such incentives will only go so far. The barriers that exist or are perceived to exist, hindering the use of active learning, must be identified for each department and lowered whenever possible. Professional development training programs, for which we have made several suggestions, can help to lower many of these barriers, but in some cases, barriers may only be lowered if there is a shift in the institutional mindset, away from viewing students as empty vessels into which we pour knowledge toward viewing them as active architects of their own learning.

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