Paper presented at the annual meeting of the American Educational Research Association (AERA). Vancouver, BC (2012).

Surveying Research University Faculty, Graduate Students and Undergraduates: Skills And Practices Important For Science Majors

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Abstract

This study was designed to evaluate appreciation for and use of techniques that promote active engagement, as viewed by three populations (faculty, graduate teaching assistants and undergraduates). We used mixed methods analysis to examine the perceived importance of skills for undergraduates as viewed by each population and the reported practices used by faculty and experienced by students. All three populations valued conceptual understanding over memorization, although students placed a higher value on memorization and other lower-order conceptual skills than did graduate students and faculty. Faculty who participated in Teaching and Learning Center programs showed more progressive instructional methods and less reliance on lecturing than those who had not. We will resurvey each population to document changes resulting from Center programs.

Objectives or Purposes

In the last decade, there has been a strong national and international call to improve science education for undergraduate students. These reports urge the adoption of active learning approaches in teaching the sciences, and have been found to enhance students' learning (Udovic *et al.*, 2002; Kitchen *et al.*, 2003; Knight and Wood, 2005; Freeman *et al.*, 2007; Walker *et al.*, 2008; Smith et al., 2011). Techniques to engage students often involve cooperative or collaborative learning and inquiry instruction that encourages students to explore the material taught.

At our university, we have created a disciplinary Teaching and Learning Center (TLC) in the chemical and biological sciences that helps faculty learn about and adopt teaching approaches that allow undergraduate students to develop critical scientific skills (e.g. group work, scientific writing, understanding the nature of science). In this study, conducted 5 years after the creation of the TLC, we sought to evaluate if there is an appreciation for and use of techniques that promote active engagement as viewed by three different populations involved in undergraduate education (Faculty, Graduate Teaching Assistants [GTAs] and Undergraduate Students).

In spring 2011 undergraduate seniors, GTAs, and faculty in the chemical and biological sciences were surveyed to explore the following research questions: (1) What do each of the three populations believe are the most important skills for undergraduates? (2) What classroom practices do faculty members report using and is this consistent with student reports of how often they experienced these practices? Our objective was to evaluate whether these different populations had similar views of critical educational goals and effective teaching practices.

Theoretical Framework

There has been growing interest in the importance of engaging undergraduate students in science education (AAAS, 2009, 2010; AAMC-HHMI, 2009; NAS, 2007; Woodin, et al., 2010).

One way to engage students is through active learning, which has been found to enhance conceptual understanding, scientific reasoning, and motivation to learn (e.g., Jensen and Lawson, 2011). Active learning promotes deeper learning of theory, concepts, and knowledge (Biggs, 1999) whereas the traditional lecture format tends to focus on scientific facts, rote learning, and note-taking.

Active learning does not automatically lead to the kind of deep understanding that one would expect from future scientists (Newmann *et al*., 1996). The knowledge of how scientists reason and think must be used to develop effective teaching methods (Weiman, 2007). For example, authentic learning (tasks that simulate real-world expert practice) has been found to enhance deep understanding, help students develop professional skills, and increase student motivation, engagement, and confidence levels (MacFarlane *et al*., 2006; Gulikers *et al*., 2008; Quitadamo *et al.*, 2008; Gilardi and Lozza, 2009). In addition, learning how researchers in the field work, think, and communicate, helps students develop their understanding of the dynamic nature of science and increase their ability in scientific problem-solving (DebBurman, 2002; Zamorski, 2002; Durning and Jenkins, 2005; DiCarlo, 2006). Therefore, in our study we focused on skills such as group work, scientific writing, and the understanding of how science applies to everyday life.

Methods and Data Sources

Context of the study: The Teaching and Learning Center

Our University enrolls 25,000 undergraduate and 9,900 graduate students in 111 undergraduate and 96 graduate programs. Within the chemical and biological sciences there are 165 faculty members (32% female), about 2,400 undergraduates pursuing majors in the biological sciences and about 400 undergraduates pursuing majors in biochemistry and chemistry. Every year there are about 130 graduate teaching assistants (experienced and new) in biological sciences and 84 in chemistry and biochemistry. In 2006, we established a College-based Teaching and Learning Center to bring focus to teaching activities in the chemical and biological sciences and help create new opportunities for faculty and graduate student development. Our goal was to increase the depth, challenge and relevancy of our curriculum and facilitate the adoption of nationally recommended approaches for teaching and learning (NRC, 2003).

Activities of the TLC include seminars by visiting teacher/scholars who have been nationally recognized for their ability to integrate teaching and research, travel grants that allow GTAs and faculty to attend teaching conferences and workshops, mandatory teaching preparatory courses for entering graduate students, individual assistance on teaching issues, development of innovative teaching approaches and assessment of the impact of these innovations on student learning.

Sample

The sample included 165 undergraduate seniors, 97 GTAs, and 71 faculty members who participated in three separate surveys designed specifically for each population. Demographic information is listed in Table 1 and is representative of the overall senior, GTA and faculty populations.

Table 1. Demographic information for seniors, GTAs and faculty

		Seniors	**GTAs**	**Faculty**
Gender	Female	55%	65%	37%
	Male	45%	35%	63%
Science discipline	Chemistry and biochemistry	18%	34%	26%
	Biological sciences	82%	62%	74%

Research Instrument and Data analysis

Three different surveys were developed for faculty, GTAs, and seniors. The survey for faculty included 28 items, the survey for GTAs included 22 items, and the survey for seniors included 5 items related to this study as well as additional questions for internal program evaluation (the survey will be included in the paper). Some of the items remained the same for all three surveys and some items differed slightly depending on the audience. Here we report on a subset of the items from the surveys. All surveys included Likert-scale questions and open-ended explanations. We used mixed-methods analysis. For the qualitative analysis of the open-ended questions, we used a modified content analysis strategy (Ryan & Bernard, 2000). The quantitative data was obtained from the Likert-scale and multiple-choice questions. The surveys were developed through an iterative process and received face validity and reliability through pilot studies and were reviewed by experts in the sciences (department chairs, faculty members, and outside evaluator), education (graduate student and statistician) and psychology (graduate student and outside evaluator).

Results and Point of View

(1) **What do seniors/GTAs/faculty believe are the most important skills for undergraduates?**

We asked faculty, GTAs and seniors to "rate the importance of the following skills for undergraduate students" on a scale of 1 to 5, where 1=not important and 5=very important (see Table 2). Table 2 reports the means and standard deviations as well as any significant differences between the three groups. For percentages, we combined the categories of 4 and 5 into one category; for means and SD we used all 5 Likert-scale categories. Almost all of the faculty, GTAs and seniors (94-99%) rated acquiring major scientific concepts as important. A high percentage of faculty, GTAs and seniors also rated as important understanding the dynamic nature of science (83-89%), understanding how science applies to everyday life (82-88%), and scientific writing (76-83%). There were no significant differences between the three groups on ratings of importance for these skills. In contrast, several significant differences were found between the three populations. Seniors rated memorizing basic facts, learning basic sets of lab skills, and remembering formulas, structures and procedures as significantly more important when compared to GTAs ($p<0.001$) and faculty ($p<0.001$). We suspect that seniors rated these skills as very important because it reflects the way that they studied as undergraduates. Especially in the introductory courses, but also in many of the upper-level courses, they are required to memorize scientific terminology, facts, and technical procedures. At the graduate level, we believe that students have already developed this foundation and can move beyond it. It was encouraging that faculty rated these basic skills as less important and rated conceptual understanding as more important, in concordance with science education reform recommendations. Working in groups was rated as more important by GTAs (70%) as compared to seniors (50%) and faculty (55%). Given the collaborative nature of modern science, it is not surprising that graduate students recognize the importance of group work. However, it was surprising that faculty members did not rate group work as an important objective for undergraduates. This may reflect the logistical difficulties of designing and facilitating group work in large undergraduate classes.

Table 2. Seniors, GTA, and faculty ratings of importance of skills for undergraduates Percentages reflect combined categories 4 (Important) and 5 (very important).

Skills for Undergraduates	**% Importance**			**Mean(SD) Likert score**			**Sig.**
	Seniors	**GTA**	**Faculty**	**Seniors**	**GTA**	**Faculty**	
Acquire major scientific concepts	97%	94%	99%	4.7(0.5)	4.6(0.7)	4.7(0.5)	NS
Understand how science applies to everyday life	85%	82%	88%	4.4(0.9)	4.3(0.8)	4.3(0.7)	NS
Understanding the dynamic nature of science	89%	83%	84%	4.4(0.8)	4.3(0.8)	4.3(0.8)	NS
Scientific writing	76%	81%	83%	4.1(0.9)	4.2(0.8)	4.3(0.8)	NS
Learn basic sets of lab skills	90%	69%	61%	4.4(0.7)	3.9(1.0)	3.7(1.0)	$p<0.001$
Work in groups	50%	70%	55%	3.4(1.1)	3.9(1.0)	3.5(1.1)	$p<0.001$
Memorizing basic facts	75%	46%	30%	4.0(0.9)	3.3(1.0)	3.0(1.0)	$p<0.001$
Remember formulas, structures, and procedures	52%	24%	19%	3.5(1.1)	2.8(1.0)	2.6(1.0)	$p<0.001$

We conducted t-tests to determine if there were significant differences in faculty responses regarding importance of skills for undergraduates between disciplines (biological sciences vs. chemical sciences), genders, course sizes, and participation in TLC programs (Table 3). Understanding the dynamic nature of science was rated significantly more important by faculty in the biological sciences (mean Likert score=4.4) than faculty in the chemical sciences (3.9). In contrast, the faculty in the chemical sciences rated learning basic sets of lab skills (4.2) and remembering formulas, structures and procedures (3.3) as significantly more important than faculty in the biological sciences (3.5 and 2.3, respectively). The data suggest that there are disciplinary differences in terms of emphasizing particular undergraduate skills.

Faculty that participated at least once in a TLC workshop or received individualized assistance from the TLC rated understanding how science applies to everyday life as significantly more important than faculty who never participated (4.5 and 4.0, respectively). We attribute this to the emphasis that the TLC places on the importance of bringing authentic research to teaching and connection to everyday life. There were no significant differences in ratings of importance based on faculty gender or course size.

Table 3. Mean Likert score and SD for faculty ratings of the importance of specific skills for undergraduates by science discipline and participation in TLC programs.

Importance of Skills for Undergraduates	Faculty Avg (SD)	Science discipline Avg (SD)			TLC participation Avg (SD)		
	Total	Bio	Chem	Sig.	Yes	No	Sig.
Acquire major scientific concepts	4.7(0.5)	4.8(0.5)	4.7(0.5)	NS	4.8(0.4)	4.6(0.6)	NS
Scientific writing	4.3(0.9)	4.3(0.8)	3.9(1.0)	NS	4.3(0.9)	4.1(0.8)	NS
Understanding the dynamic nature of science	4.3(0.8)	4.4(0.8)	3.9(0.7)	p<0.05	4.4(0.8)	4.2(0.8)	NS
Understand how science applies to everyday life	4.3(0.7)	4.4(0.7)	4.2(0.7)	NS	4.5(0.7)	4.0(0.7)	p<0.05
Learn basic sets of lab skills	3.7(1.0)	3.5(1.0)	4.2(0.6)	p<0.05	3.8(0.8)	3.4(1.3)	NS
Work in groups	3.5(1.1)	3.5(1.2)	3.4(0.8)	NS	3.6(1.2)	3.2(0.9)	NS
Memorizing basic facts	3.0(1.0)	3.0(0.9)	3.1(1.2)	NS	3.0(1.0)	2.9(1.0)	NS
Remember formulas, structures, and procedures	2.6(1.0)	2.3(0.8)	3.3(1.2)	p<0.05	2.5(0.9)	2.8(1.3)	NS

(2) What classroom practices do faculty members report using and is this consistent with student reports of how often they experienced these practices?

We asked faculty members, "How often did you use each of the following practices?" and they responded on the following scale: not used, once per semester, a few times a semester, most class sessions, and almost every class session. We combined the top three ratings into practices used at least a few times a semester (Table 4). Overall, all or most faculty reported that they use the following practices at least a few times a semester: answering questions from individual students in class (100%), extensive lecturing (98%), communicating course goals and objectives (90%), asking students to interpret graphical information (90%), and class discussions (87%). The least used practice was reflective writing/journaling (12%). Around half of the faculty reported using group work during class time (53%) or outside of class time (49%), which matched the seniors' perceptions (55% responded that they had experienced group work in many or most of their classes, Table 5). We will present additional student report data in the full paper.

We conducted t-tests to determine if there were significant differences in faculty responses regarding classroom practices by gender and TLC participation (Table 4). It was encouraging to see that all faculty who participated in TLC programs reported practicing active learning features such as group work, using personal response systems (clickers), and conducting out of class discussions significantly more than those who did not participate in TLC programs. TLC participants also reported using extensive lecturing less frequently than non-participants.

We also found gender differences within classroom practices, such as female faculty using group work more than male faculty, but at our institution gender is confounded with faculty rank (the majority of non-tenure-track lecturers are female) so the effect could result from differences in teaching style between tenured/tenure-track and non-tenure-track faculty. When we performed a t-test between non-tenure-track lecturers and tenured/tenure-track faculty, we found that lecturers were significantly more likely to use group work during class than tenured/tenure-track faculty ($t=-2.96$ (56), $p<.05$).

Table 4. T-tests and average faculty responses to classroom practices overall and by participation in TLC professional development programs. (The Likert scale included the following scale: 1= not used, 2=once per semester, 3=a few times a semester, 4=most class sessions, and 5=almost every class session).

Classroom Practices	Faculty Percentage	Faculty Avg (SD)	TLC Participation Avg (SD)		
		Total	Yes	No	Sig
Answering questions from individual students in class	100%	4.6 (0.5)	4.6(0.5)	4.6(0.5)	NS
Extensive lecturing	98%	4.5 (0.8)	4.4(0.8)	4.8(0.4)	p<0.05
Communicating course goals and objectives	90%	3.5 (0.9)	3.5(0.9)	3.6(1.0)	NS
Asking students to interpret graphical information	90%	3.4 (1.0)	3.4(1.0)	3.4(1.0)	NS
Class discussions	87%	3.4 (1.2)	3.5(1.1)	3.0(1.4)	NS
Multimedia instruction	72%	2.8 (1.2)	2.9(1.2)	2.6(1.4)	NS
Real-life problems	61%	2.5 (1.3)	2.6(1.3)	2.4(1.4)	NS
Group work during class time	53%	2.4 (1.3)	2.7(1.3)	1.4(0.9)	p<0.001
Group work outside of class time	49%	2.4 (1.4)	2.6(1.5)	2.1(1.2)	NS
Debates in class	39%	2.0 (1.2)	2.1(1.2)	1.7(1.1)	NS
Out of class discussions	38%	2.1 (1.4)	2.3(1.5)	1.4(0.9)	p<0.05
Reflective writing/journaling	12%	1.4 (0.8)	1.5(0.9)	1.1(0.5)	NS
Personal Response System	30%	2.0 (1.6)	2.2(1.8)	1.2(0.8)	p<0.05
Graphic organizers	28%	1.6 (1.0)	1.7(1.0)	1.4(0.9)	NS
Online module with immediate feedback	21%	1.6 (1.2)	1.7(1.2)	1.5(1.3)	NS
Games, simulations, role-play	18%	1.5 (0.9)	1.5(0.9)	1.4(0.9)	NS

Table 5. Percentage of seniors' responses to how often practices are used in their classes

Classroom Practices	None	Rarely	Mostly Intro	Mostly Upper	Most Courses
Extensive lecturing	1%	3%	3%	6%	87%
Communicating course goals and objectives	0%	3%	16%	14%	66%
Answering questions from individual students in class	1%	14%	6%	21%	58%
Asking students to interpret graphical information	1%	13%	15%	30%	41%
Multimedia instruction	1%	26%	19%	18%	37%
Graphic organizers	16%	37%	15%	15%	18%
Group work outside of class time	1%	26%	38%	22%	13%
Class discussions	2%	22%	31%	35%	11%
Real-life problems	1%	26%	22%	41%	10%
Group work during class time	8%	37%	32%	14%	9%
Personal Response System	5%	12%	68%	7%	8%
Out of class discussions	10%	50%	26%	10%	4%
Debates in class	24%	42%	14%	17%	3%
Online module with immediate feedback	9%	29%	58%	2%	2%
Reflective writing/journaling	31%	41%	20%	6%	2%
Games, simulations, role-play	36%	46%	14%	3%	1%

Scientific significance of the study

In this study we sought to evaluate the perceived importance of skills for undergraduate science students as viewed by three different populations involved in undergraduate education (Faculty, GTAs and Undergraduate Students). We also explored the reported practices used by faculty and experienced by students to evaluate the extent to which active learning methods were being incorporated into the undergraduate curriculum. The three populations placed high value on conceptual understanding, and understanding the process and applications of science. Differences were found in students rating lower-order conceptual skills (e.g., memorizing facts, structures, and formulas) as higher than faculty. Faculty who participated in TLC programs reported using more progressive instructional methods (e.g., use of technology and group work) and less reliance on lecturing than those who did not participate in TLC programs. We intend to administer the survey again next year to measure growth and the influence of the TLC.

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