Student and Faculty Views on Process of Science Skills at a Large, Research-Intensive University

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The Association of American Colleges and Universities ranks multiple process of science (POS) skills among the top-10 skills employers seek in college graduates. As part of an effort to explore and align the emphasis on POS skills in our science departments, we sought three things: (a) to determine if faculty and students felt enough time was devoted to POS skills, (b) to identify the skills that science students and faculty felt were important to acquire from an undergraduate education, and (c) to evaluate whether there were differences in these views among disciplines. We found that faculty and students agreed on the amount of time spent in class on POS skills, but students thought that amount of time was sufficient, whereas faculty did not. Further, students and faculty placed a high importance on the POS skills of problem solving/critical thinking, communicating results, and interpreting data. We did not find differences among faculty of different science disciplines on the most highly ranked POS skills, but we did in students. The findings of this study have informed curricular discussions and decisions.

Through recent and extensive collaborative efforts, educational researchers have highlighted numerous skills that are foundational to scientific endeavors (American Association for the Advancement of Science, 2009; Brewer & Smith, 2011; Gott, Duggan, & Johnson, 1999; Harwood, Reiff, & Phillipson, 2002; NGSS Lead States, 2013; Zimmerman, 2000). These skills can be termed process of science (POS) skills (Coil, Wenderoth, Cunningham, & Dirks, 2010). POS skills broadly include *reasoning* (Bao, Cai, Koenig, Fang, & Han, 2009), *communication* (Dirks & Cunningham, 2006), *experimental design* (Dirks & Cunningham, 2006; Wilke & Straits, 2005), and *data analysis* (Dirks & Cunningham, 2006). More specifically, these skills include data interpretation, problem solving, critical thinking, oral and written communication, collaborating with others, integration of studies, and metacognitive activities (Coil et al., 2010). Although all of these skills are integral to doing science, they are also universally transferable skills. POS skills are highly applicable outside of science and can help students succeed in many careers (American Association of Colleges and Universities, 2013). Further, by acquiring POS skills, students become more educated citizens of our society and can value how scientific knowledge is gained differently than other sorts of knowledge (Brickman et al. 2012). Educators in the science disciplines are reaching a consensus on the importance of teaching students to process information in the manner of scientists (e.g., Brewer & Smith 2011; Coil et al., 2010).

POS skills need to be taught with intentionality because they do not develop spontaneously (Mestre, 2008; Zimmerman, 2000). It can be difficult to balance time for both content and skills in scientific courses (Zimmerman, 2000); in the end, courses usually emphasize content rather than skills (Dirks & Cunningham, 2006). If college curricula are to adopt a stronger emphasis on practicing and improving POS skills, it is important to reflect on the relative importance of individual skills as learning objectives.

As part of a major transformation effort to teach students how to think like scientists at a large, research-intensive university, we aimed to incorporate intentional teaching of POS skills across science disciplines. However, before we could do so, we needed to establish a baseline of how POS skills were currently viewed by faculty and students. Numerous studies (e.g., Kuh, 2001; Tanner, 2009; Tobias, 1992; Wood, 2009) have shown that student buy-in to, and engagement with, the subject matter is important. If instructors focus on teaching POS skills in which students see no relevance, students will likely resist and resent the teaching of them. Hence, we asked whether the faculty instructors and students viewed similar POS skills as important at this institution. In this effort, we surveyed students and faculty from multiple science disciplines. We included multiple disciplines because most science majors take courses in several different science fields. As a result, they are exposed to POS skills in more than one science discipline. The findings from this study informed curricular discussions within and between disciplines. Further, the study provides insights regarding when faculty may need to educate students on *why* certain skills are important.

Aims of the study

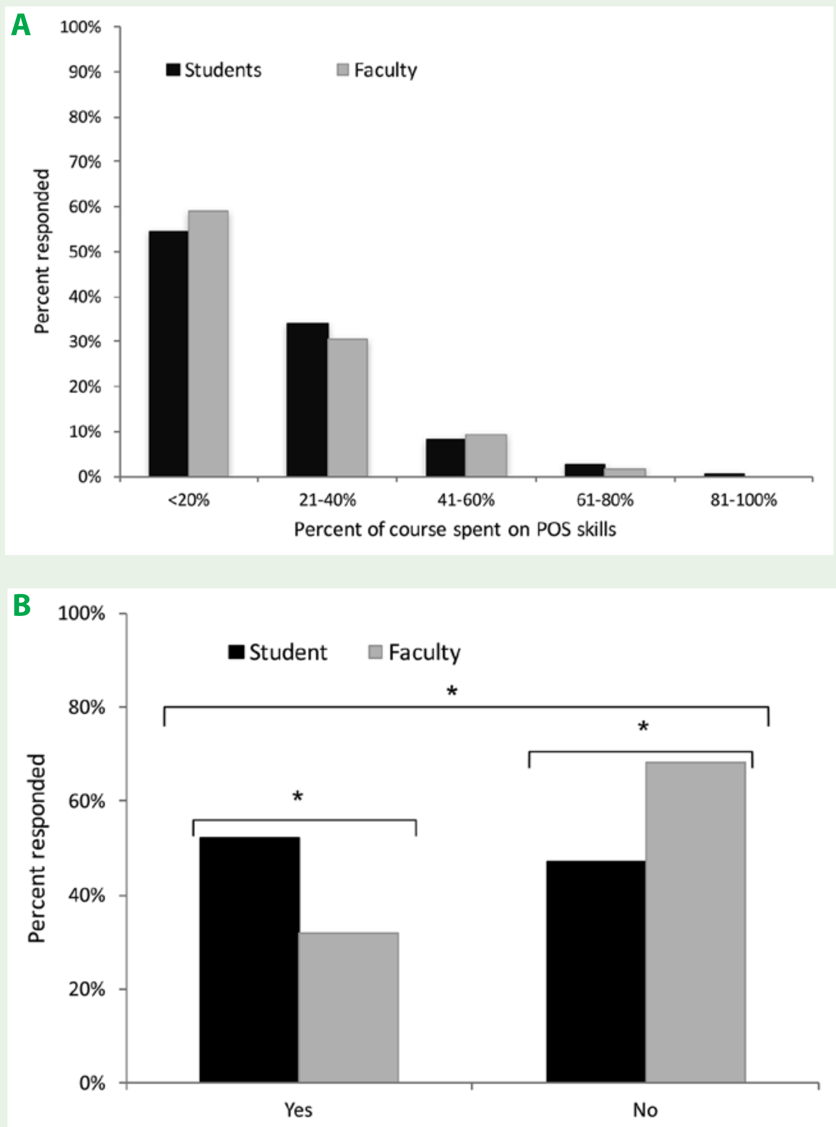
The aims of this study were threefold. First, we investigated whether students and faculty agreed in their assessment of how much time was placed on POS skills in courses and their views on how much time should be spent on them to determine the amount of buy-in. Second, we asked whether students and faculty agreed on which POS skills were important for their career goals or as part of an undergraduate's education (respectively). Third, as we were surveying faculty and students across science disciplines, we explored differences in prioritization of specific POS skills across the disciplines. The results presented here are reflective of this university and could be informative for other institutions and/or departments interested in increasing the time spent on, and retention of, POS skills.

Methodology

This work was conducted at a large, land-grant university in the Midwest, the mission of which specifically includes the teaching of science and technology. In 2010, this university received a grant from the Howard Hughes Medical Institute to integrate POS skills across the curriculum. As an important step in this integration, we sought to understand faculty and student views of the importance of specific POS skills in the curricula. To better define student and faculty views on the importance of POS skills, we surveyed undergraduate science students and teaching faculty at our university, using a survey

FIGURE 1

(A) Faculty and students agree on the amount of time spent in class on process of science (POS) skills. (B) Faculty and students disagree that the amount of time spent in class on POS skills is sufficient. Asterisk denotes significant difference.



instrument developed by Coil et al. (2010). This survey was designed, validated, and used to assess biology faculty opinions on undergraduate students learning POS skills by Coil et al. (2010). Because we were interested in views of students and faculty from multiple science disciplines, we removed all questions from the survey that were biology specific—for example, "Ability to use basic online bioinformatics tools (NCBI databases, BLAST, etc.)." For the student survey, we also changed the text from asking about teaching to asking about learning.

The survey asked how much time they spend teaching/learning POS skills in class ("What percentage of time do you estimate that you spend learning science process skills [as opposed to content] in your science classes?") and whether there was a need to spend more time teaching POS skills ("Do you feel that the amount of time you spend learning science process skills is sufficient for your career goals?"). The phrase *science process skills* was used in place of *POS skills*. Neither of those terms were defined for the survey takers; instead, takers were queried on specific POS skills (e.g., "understanding basic statistics"). Answers to these questions provided insight to student and faculty perceptions regarding the importance of POS skills in general. To determine the importance that survey respondents placed on specific skills, the survey included questions from the validated Coil et al. 2010 instrument. Respondents used a Likert scale (1 = *unimportant* to 5 = *very important*) to characterize 20 POS skills. For example, a question from the student version reads, "Please rank how important it is for you to obtain the following science process skills by the time you graduate with an undergraduate degree." Some of the POS skills addressed in this survey have been identified by the American Association of Colleges and Universities (AACU) as important skills (AACU, 2013). Survey respondents were also asked which of the POS skills listed were most important for student career goals. For example, the question from the student survey reads, "Which of the following skills are the most important for your career goals? Choose the 3 that are most important to you."

The distribution of the survey was not associated with a class; it was sent to all currently enrolled students and faculty in the selected science departments. The survey was distributed by e-mail and contained a link to the survey website (implemented by Qualtrics). There was no incentive given to take the survey besides the opportunity for the takers to share their opinions. All responses were anonymous. This study was deemed exempt from IRB oversight (ID# 11-529), meaning the institutional review board gave us approval to conduct the study but did not see need to monitor the implementation of it. Surveys were sent to faculty and students in 2012 (surveys are available at http://www.nsta.org/college/connections.aspx).

We sent the survey to 447 faculty across six general science fields (applied biology, biology, chemistry, geology, physics, and psychology; see http://www.nsta.org/college/connections.aspx for more information on the categorization of science departments). We use the term *faculty* to include all teaching employees at our institution (tenured, tenure track, senior lecturer, lecturer). The student survey was sent to 2,680 undergraduates in majors falling within the same six science fields.

All statistical analyses were conducted in JMP Pro 11.0 (SAS Institute, Cary, NC). To evaluate if faculty and students felt they taught or were taught (respectively) sufficient POS skills, we compared affirmative and negative responses using Pearson's χ^2 test. We also examined these data to determine if there were any differences among students based on year in college. Because the sample size for first-year

FIGURE 2

Faculty and student response to the survey question, "Which of the following skills are the most important for your career goals? Choose the 3 that are the most important to you." A greater percentage of faculty view "interpreting data" as a very important skill than students and a greater percentage of students view "working collaboratively to accomplish a task" as more important than faculty did. The asterisks denote significant differences.

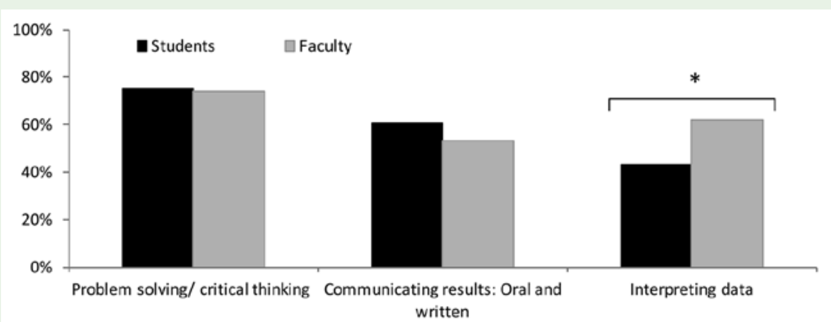
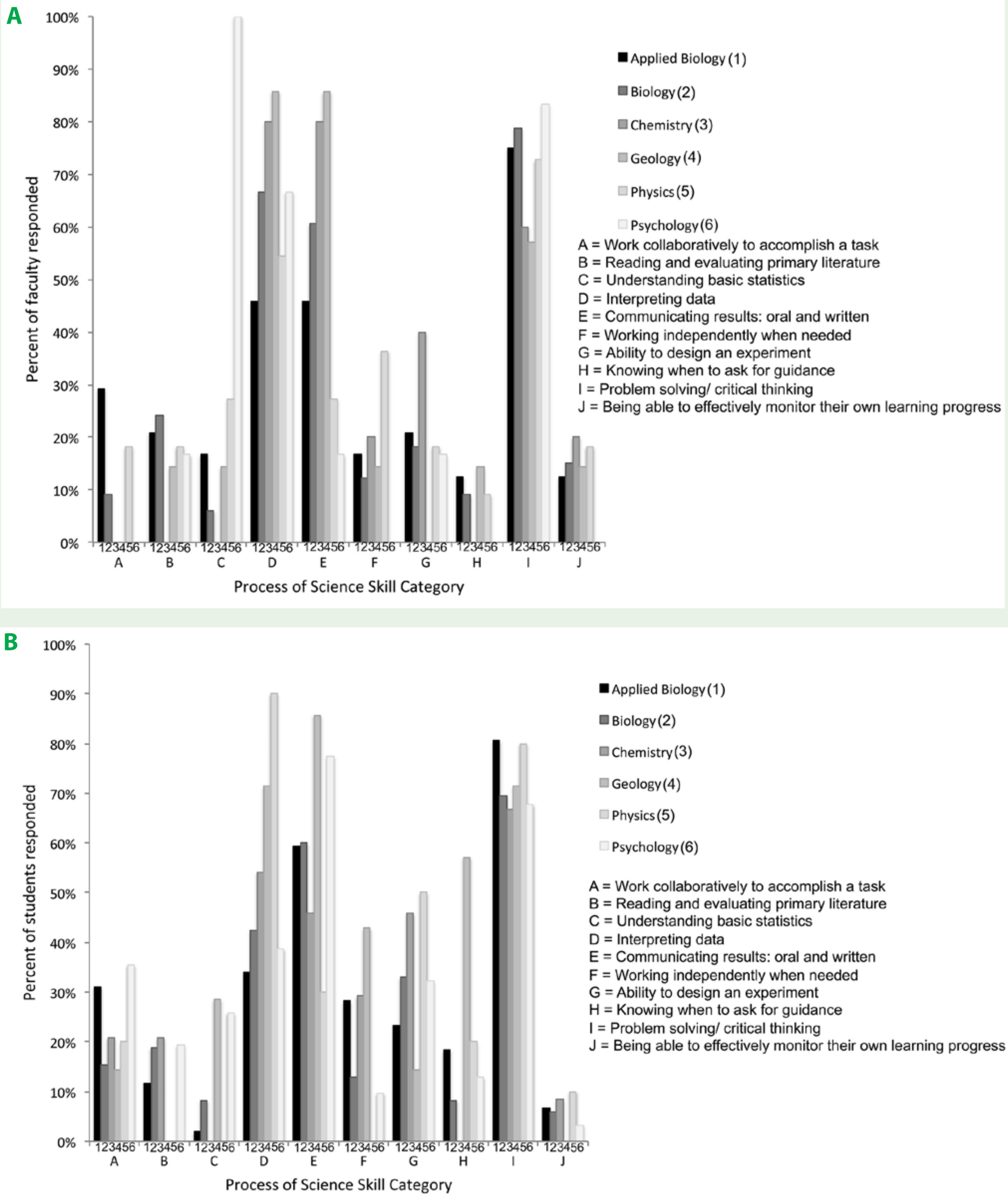


FIGURE 3

Faculty and student response to the survey question, "Which of the following skills are the most important for your career goals? Choose the 3 that are the most important to you," sorted by discipline. (A) Percentage of faculty who ranked a skill as *very important* in the above question; (B) Percentage of students who ranked a skill as "very important" in the above question. Letters on *x*-axis correspond to the category of process of science (POS) skill.



students was very small ($n = 3$), we grouped students into two categories: novice (students in their first or second year) and expert (students in their third, fourth, or fifth year). To compare the two groups of students' views on the amount of time spent on POS skills in the courses, we used a Pearson's χ^2 test. To determine if novices and experts agree on whether this was sufficient, we used Fisher's Exact Test.

We compared the percentage of faculty and students who reported a POS skill as *very important* for an undergraduate degree (Question 3) using Pearson's χ^2 test. Question 3 ("Please rank how important it is for you to obtain the following science process skills [examples of such skills are listed in the left column] by the time you graduate with an undergraduate degree") asked faculty or students to rank (from *unimportant* to *very important*) 20 POS skills (surveys available at http://www.nsta.org/college/connections.aspx). To investigate the data from Question 4 regarding skills needed to achieve career goals ("Which of the following skills are the most important for your career goals? Choose the 3 that are most important to you"), we compared faculty and student responses to the skills individually using Fisher's Exact Test (FET).

To determine if faculty and students from across disciplines ranked POS skills differently, we analyzed the survey results from Question 3 using Pearson's χ^2 test. Comparisons for Question 4 among disciplines were also made using Pearson's χ^2 test.

Science courses are taught in 50-minute blocks on Monday, Wednesday, and Friday or in 80-minute sessions on Tuesdays and Thursdays. The distribution of courses during a week was not discipline specific (and was therefore not included in the analysis). Courses varied within and among disciplines in the amount of time spent in active learning (and therefore was not included in the analysis).

Results

Ninety-four faculty members responded (21%). Of the faculty respondents, 65% were tenured, 20% were tenure track, 2% were senior lecturers, 7% were lecturers, and 6% were other (such as affiliate faculty). Three hundred and seventy-two students responded (14%). Of the student respondents, 10% were freshman, 19% were sophomores, 29% were juniors, and 34% were seniors; 8% marked "other" (e.g., nonmatriculated students).

Aim 1: Time spent on POS skills

Faculty and students were in agreement on the amount of time in class that was being spent on POS skills, but they differed in opinion as to whether more emphasis was needed. Most of the students and faculty instructors indicated that less than 20% of class time was dedicated to POS skills. Approximately a third of the students or faculty surveyed estimated that 21%–40% of the class time was devoted to POS skill development. Overall, the differences between faculty and student responses were not significant (Figure 1A; $\chi^2 = 6.97$; $p = 0.14$). However, faculty and students disagreed on how much time should be spent on POS skills in the classroom (Figure 1B; $\chi^2 = 11.74$, $p = 0.0006$). Sixty-eight percent of faculty vs. 36% of students felt not enough time was spent on POS skills ($\chi^2 = 9.69$, $p = 0.002$), whereas 64% of students versus 32% of faculty felt sufficient time was spent on these skills ($\chi^2 = 15.92$, $p < 0.0001$). Novice and expert students agreed on the amount of time spent on POS skills in the classes ($\chi^2 = 6.13$; $p = 0.19$), and they did not disagree on the sufficiency of time spent on POS skills in classes (FET, $p = 0.64$).

Aim 2: Importance of POS skills

To determine whether faculty and students had differing views on which POS skills were important and to compare the responses to those from prior published studies at other institutions (Coil et al., 2010), we asked "Please rank how important it is for you to obtain the following science process skills (examples of such skills are listed in the left column) by the time you graduate with an undergraduate degree." When the responses across disciplines were combined, there was agreement between faculty and students ($\chi^2 = 14.95$, $p = 0.092$).

Next, we asked faculty and students to identify the skills that were most important for student career goals. The survey question to students was, "Which of the following skills are most important for your career goals. Choose 3 that are most important to you." Some of the key findings are illustrated in Figures 2 and 3. Most faculty and students thought critical thinking (FET, $p = 0.89$) and oral and written communication of results (FET, $p = 0.13$) were the highest priority. More faculty listed interpreting data as a high priority skill, compared with students (FET, $p = 0.007$). Conversely, students were more likely to list "ability to design an experiment" as one of the top three POS skills that they should be learning (FET, $p = 0.009$).

Aim 3: Discipline-specific views on POS skills

Although POS skills should be valued across disciplinary boundaries, we considered the possibility that there might be differing emphases across disciplines. To address this, we compared faculty and student responses for each POS skill queried. The rankings of how faculty and students, sorted by discipline, viewed POS skills as important for an undergraduate education (Question 3) are shown in Tables 1 and 2, respectively. There were no significant differences among disciplines for faculty in importance of skills based on rankings rather than percentage that viewed a skill as "very important" (Table 1). Faculty placed a high importance on student learning goals associated with interpreting data, critical thinking, and communication skills. Students, on the other hand, did rank some skills differently by discipline (Table 2). For example, biology, applied biology, and physics students all ranked "problem solving/critical thinking" the highest. Note that physics students gave equal weight to "ability to design an experiment: identifying and controlling variables." Geology students ranked "communicating results: oral" as the most important skill. Chemistry students scored "ability to design an experiment: development of proper controls" the highest. Psychology students thought the "ability to create a testable hypothesis" was the most important skill, and they thought "understanding basics statistics" was a more important skill to learn compared with student respondents from other majors.

As queried in Question 4, in which faculty and students were asked to identify three POS skills important to achieving career goals, discipline did not have a dramatic effect on faculty answers ($\chi^2 = 50.87$, $p = 0.25$; Figure 3A), but it did for students ($\chi^2 = 78.21$, $p = 0.02$; Figure 3B). For example, 12%–21% of students majoring in biology, applied biology, chemistry, or psychology identified reading and evaluating primary literature as one of the top three POS skills, while geology and physics majors did not identify this as a top-three skill (Figure 3B). This is consistent with the student rankings of this skill on a 5-point Likert scale, reported in Table 2.

Discussion

POS skills are highly valued by employees of college graduates (AACU, 2013). Considering that many science majors do not end up with a career that directly pertains to their major (only one in four STEM [science, technology, engineering, and mathematics] majors go into STEM careers; Landivar, 2013), the skills they learn outside of the content area could be equally or even more important than the content itself. However, both instructors and students have been heavily indoctrinated in the importance of teaching and learning content. As a result, POS skills are frequently neglected in the classroom. With the development of *Vision and Change* (Brewer & Smith, 2011) and the *Next Generation Science Standards* (NGSS Lead States, 2013), there is a movement to increase the number of POS skills taught in the classroom at the primary, secondary, and college levels.

There were three major aims of this study: first, to determine if faculty and students from six different science disciplines at this research-intensive university felt the same amount of time was devoted to POS skills in classes and if this amount of time was sufficient; second, to determine if students and faculty viewed the same POS skills as being an important part of an undergraduate education; and third, to determine if faculty and students from different science disciplines ranked POS skills differently.

Aim 1: Time spent on POS skills

To gauge the overall emphasis placed on POS skills in class, the survey queried faculty members and students on the amount of time each estimated was spent on POS skills in class. Both groups agreed on how much time was devoted to POS skills, which reciprocally supports both the student and faculty self-reports on this question. In an effort to determine how important faculty and students thought teaching POS skills was (for the purposes of this survey, that was determined by the amount of time that should be spent on POS skills), we asked both groups if enough time was spent on these skills. More faculty than students thought insufficient time was spent on these skills, and more students than faculty thought sufficient time was spent on POS skills. These results suggest that students and faculty may not view teaching/learning POS skills as equally important. At our university, this could be for several reasons. First, instructors do not communicate to students why learning these skills is important. Although the importance of these skills may seem obvious to faculty, if students have previously experienced a lack of emphasis on them, the importance of the skills may not be evident to students. Second, in many classes, instructors may predominantly test factual knowledge, rather than student progress toward skill development. As a result, students are indirectly receiving the message that being able to perform POS skills is not as important as content knowledge. Third, standardized tests, such as the MCAT, formally did not emphasize POS skills, although this changed with the newly formatted MCAT (American Association of Medical Colleges; https://www.aamc.org/students/applying/mcat/). And fourth, respondents may agree that POS skills such as critical thinking are important, but students may be more skeptical than their instructors that student skill development would be advanced by spending additional class time focused on POS skills.

Aim 2: Importance of POS skills

Regarding skills important for an undergraduate science degree (Ques-

TABLE 1

Faculty rankings of process of science (POS) skills sorted by discipline. Values given are averaged Likert scores from Question 3. The highest average score for each department group is in bold. χ^2 and *p* values are given in right-most columns. The null hypothesis was that there would not be differences in rankings of POS skills among departments.

Science process skill	Biology	Applied biology	Geology	Chemistry	Physics	Psychology	χ^2	*p*
Interpreting data: graphs and data	**4.88**	4.58	**5.00**	**5.00**	4.55	4.67	11.71	0.31
Interpreting data: ability to construct an argument from data	**4.88**	4.30	4.86	**5.00**	4.64	4.67	10.90	0.37
Problem solving/critical thinking	4.78	**4.94**	4.57	4.67	**4.91**	**4.83**	13.25	0.21
Communicating results: Oral	4.50	4.25	4.71	4.33	4.45	**4.83**	8.80	0.55
Communicating results: Written	4.44	4.57	4.86	4.50	4.73	4.67	7.60	0.67
Creating the appropriate graph from data	4.35	4.10	4.43	4.33	4.18	4.67	11.17	0.74
Working independently when needed	4.31	4.57	4.86	3.50	4.55	**4.83**	13.70	0.08
Knowing when to ask for guidance	4.27	4.41	4.71	3.83	4.45	**4.83**	11.14	0.35
Understanding basic statistics	4.26	4.58	4.57	4.67	4.18	4.29	4.60	0.92
Conducting an effective literature search	4.17	4.16	4.43	4.00	4.27	4.50	10.02	0.97
Ability to design an experiment: Development of proper controls	4.14	3.88	4.00	4.00	3.73	4.17	12.07	0.67
Ability to design an experiment: Identifying and controlling variables	4.12	3.94	4.14	4.00	3.82	4.00	5.27	0.99
Being able to effectively monitor their own learning process	4.07	4.41	4.00	3.17	4.18	4.20	18.54	0.24
Ability to design an experiment: Proper alignment of experiment and hypothesis	4.03	3.90	4.00	4.17	3.82	4.00	5.34	0.99
Being able to infer plausible reasons for failed experiments	3.98	4.05	4.14	3.50	3.82	4.33	10.77	0.77
Reading and evaluating primary literature	3.93	4.19	4.43	4.17	3.73	4.33	11.04	0.95
Ability to create a testable hypothesis	3.90	3.69	4.57	4.17	4.18	4.00	6.45	0.97
Working collaboratively to accomplish a task	3.83	4.13	4.14	3.67	3.91	4.33	9.09	0.87
Creating a bibliography and proper citations of references	3.67	4.50	3.86	3.67	4.00	4.67	21.41	0.37
Being an effective peer mentor	2.99	3.52	3.29	3.17	3.09	3.50	10.00	0.97

tion 3), there was only a trend for students and faculty to differ. When asked to identify the three most important POS skills on career goals, faculty and students at this university concurred on two of the three skills. Both faculty and students agreed that problem solving/critical thinking and communicating results were most important. However, student and faculty views diverged for the third skill: Faculty thought interpreting data was more important than students did. Students still thought it was important, just not as important as faculty did. Further down the list, the data point to another difference in opinion: Students placed greater

TABLE 2

Student rankings of process of science (POS) skills sorted by discipline. Values given are averaged Likert scores from Question 3. The highest average score for each department group is in bold. χ^2 and *p* values are given in right-most columns. Students' values of skills listed in italics differ by area of study. The null hypothesis was that there would not be differences in rankings of POS skills among students of different departments.

Science process skills	Biology	Applied biology	Geology	Chemistry	Physics	Psychology	χ^2	*p*
Problem solving/critical thinking	**4.81**	**4.77**	4.75	4.64	**4.9**	4.65	52.03	<0.0001
Interpreting data: ability to construct an argument from data	4.6	4.5	4.63	4.57	4.5	4.47	21.11	0.27
Ability to design an experiment: Identifying and controlling variables	4.54	4.24	4.38	4.64	**4.9**	4.5	31.54	0.14
Ability to create a testable hypothesis	4.52	4.27	4.63	4.64	4.7	**4.68**	30.82	0.16
Ability to design an experiment: development of proper controls	4.52	4.24	4.38	**4.71**	4.7	4.38	36.16	0.05
Communicating results: written	4.52	4.65	4.75	4.36	4.2	4.71	30.01	0.18
Communicating results: oral	4.42	4.65	**4.88**	4.21	4	4.47	37.51	0.005
Interpreting data: graphs and data	4.39	4.24	4.5	4.57	4.7	4.29	19.43	0.37
Knowing when to ask for guidance	4.39	4.61	4.63	4.36	4.4	4.29	14.27	0.71
Being able to infer plausible reasons for failed experiments	4.39	4.44	4.5	4.64	4.5	4.26	49.84	0.001
Working independently when needed	4.34	4.69	4.38	4.14	4.6	4.47	41.28	0.001
Creating an appropriate graph from data	4.29	4.16	4.63	4.14	4.7	4.38	15.58	0.62
Reading and evaluating primary literature	4.23	4.24	3.13	4.29	3.8	4.44	63.08	<0.0001
Being able to effectively monitor your own learning process	4.23	4.45	4.25	4.21	4.3	4.44	17.76	0.81
Working collaboratively to accomplish a task	4.22	4.43	4.38	4.21	4.3	4.18	24.7	0.13
Understanding basic statistics	4.14	4.23	4.13	4.07	4	4.59	29.74	0.04
Conducting an effective literature search	4.13	4.18	3.25	4.29	3.5	4.24	32.12	0.12
Creating a bibliography and proper citations of references	4.06	3.9	4.38	4.29	3.6	4.32	31.89	0.13
Being an effective peer mentor	3.77	4.06	4.38	3.86	4.2	3.82	26.54	0.33

importance on the skill of working collaboratively to accomplish a task compared with faculty respondents.

Why do students and faculty instructors differ in their relative rankings of the importance of data interpretation? It is possible that students taking the survey did not clearly understand the distinction between problem solving/critical thinking and data interpretation. These skills were not explicitly defined in the survey because most were viewed as self-explanatory, but the possible overlap between critical thinking and data interpretation could have been more directly addressed. Faculty may spend more time thinking explicitly about these skills than students, and as a result, may more clearly delineate between critical thinking and data interpretation. In other words, faculty may interpret the meaning of these skills differently than students. Additionally, as students progress through college, they move along the novice-to-expert continuum (Conley 2011), so within the population of students, there may be variation with the interpretation of these skills. However, our results did not find any differences between novices and experts. This issue of differences in interpretation between faculty and students is not insignificant and raises the possibility of misalignment between the two survey groups. If students did not distinguish between critical thinking and data interpretation, then the finding of faculty favoring data interpretation over that of students could be negated.

Faculty could experience resistance from students to the devotion of class time to POS skills as students do not see the importance of these skills to the same extent as faculty. One way to avoid this resistance and help students understand the importance of these skills could be for faculty to explicitly explain why the skills are important (Abd-El-Khalick & Lederman, 2000; Lederman, Abd-El-Khalick, & Bell, 2001; Stone, 2014). For example, biology faculty placed a high value on interpretation of graphs (4.88 on a scale of 1 to 5), whereas students were less convinced (4.39). Conversely, students placed a high level of importance on experimental design (4.54), whereas faculty ranked this as having less importance (4.14). These discrepancies suggest that students could be more invested in learning data interpretation skills if they believed that these skills were a stepping stone to experimental design. As another example, geology students did not highly rank reading, evaluating, and searching for primary literature, but faculty did. By faculty both encouraging students to practice these skills and being explicit as to why they are important, students could develop appreciation for them.

Aim 3: Discipline-specific views on POS skills

We determined that there were no significant differences for importance of POS skills in an undergraduate degree among disciplines for faculty, but there were so for students. This same pattern held for faculty and student views on the importance of POS skills for career goals: Discipline did not have an effect on faculty views but did so for students. The degree to which there are differences among the disciplines in the student sample and not in the faculty could be due to sample size differences: Almost four times as many students took the survey as faculty did. Furthermore, faculty members, as a general rule, have devoted years to learning how to communicate across subdisciplines and to understanding the crosscutting themes and the associated POS skills. Still, we might expect to see some trends for differences in how faculty in diverse scientific fields ranked specific skills. For example, some disciplines address questions through experimental approaches in a research lab, whereas others are more reliant on correlative or observational studies. Fields also differ in their reliance on qualitative versus quantitative data. Students are, by definition, earlier in their careers, and they have likely had little experience in interdisciplinary scholarship. Student responses would be expected to be more strongly influenced by their current coursework and to reflect both the subtle and overt differences in scientific fields. The student responses may also reflect their career aspirations and the POS skills that they most commonly associated with those careers.

One of the differences among students is the importance of reading primary literature. Because most students are introduced to primary literature in college, the importance students see in being able to interpret it could be due to a combination of their exposure to it and the importance faculty members give it (data from Question 3, shown in Table 2). The same explanation most likely applies to the importance psychology students place on understanding basic statistics. Many psychology programs require students to take specific psychology statistics classes. Most other sciences do not teach their own statistic courses, and some disciplines at our university do not require undergraduate majors to take a statistics class, thereby implicitly sending the message that understanding basic statistics is not an important POS skill. The result that students from some disciplines (such as geology) differently rank oral communication skills than others could be an artifact of course emphasis. Giving oral presentations may be more common in geology courses than in courses in other science disciplines.

Implications

Considering that science can be applied in many different contexts, most of them being different from those taught in class, the ability of students to transfer skills from science classes to application in careers postcollege is beneficial to them (AACU, 2013). Hence, students should be motivated to learn POS skills, and faculty should be motivated to teach them. However, it is important that if faculty increase their teaching of POS skills they also increase their assessment of them or else they will indirectly send the message that POS skills are not actually that important. Further, we suggest the POS skills are not taught in isolation, rather integrated with content. This integration of POS skills with content will exemplify how scientists use these POS skills. Assessing students' POS skills can be more challenging and potentially time consuming to implement and construct than assessment of content alone, a likely reason why they are not emphasized in most classes (Coil et al., 2010; Stone, 2014). Test banks associated with textbooks are now including questions of increased complexity and POS skills. This trend is also beneficial because these test banks often integrate POS skills with content, as promoted by the *NGSS* (NGSS Lead States, 2013). We hope the results of this study can encourage faculty and students alike to embrace the explicit teaching and learning of POS skills as well as to integrate them with content.

For example, at this large, Midwestern university, these findings informed and helped to catalyze curricular discussions and decisions. The data were presented to faculty from several departments, inspiring discussions about learning goals for diverse STEM majors and how faculty communicate those goals to students. This work also informed decisions to expand course-based undergraduate research experiences as many of these skills can be taught and applied through such experiences. Also, large-enrollment courses have recruited greater numbers of peer mentors or undergraduate learning assistants. This serves two purposes: providing the peer mentoring experiences that students view as important and helping students in large-enrollment courses to learn and practice POS skills (Cervato, Gallus, Slade, Kawaler, & Marengo, 2015; Elliott et al., 2016; Moss & Cervato, 2016). This recognizes both the pedagogical advantages to learning POS skills of this approach and the importance that students place on these experiences in learning POS skills.

In summary, we found that students and faculty primarily view the same skills as important, but the students do not necessarily see the importance in learning POS skills compared with content. There were no differences among emphasized POS skills for the faculty, but there were so for the students. The results of this study also highlight the importance of communicating instructors' rationales for teaching POS skills to students as well as taking into consideration what POS skills students view as important. Communicating rationales with students can increase student buy-in of time and effort devoted to learning POS skills. Future, broader studies could examine in greater depth what faculty and students view as barriers to implementing and learning POS as well as how faculty think POS skills should be integrated into courses through observations and interviews. In future studies, we hope to examine any relationships between emphasis on teaching POS skills and attitudes toward teaching in different departments and disciplines.

We hope that this survey and the results of it will be useful to faculty and administrators who contemplate both what material is included in a class and to what information students are exposed across scientific fields. Considering that many employers view POS skills to be desirable in college graduates, we encourage the intentional incorporation of these skills, and assessment of them, in courses across scientific disciplines, with instructors communicating to students why these skills are important. ■

Acknowledgments

This study was funded by a grant to Iowa State University by the Howard Hughes Medical Institute through the Precollege and Undergraduate Science Education Program. We thank Craig Ogilvie for his ongoing support throughout the duration of the project and all of the faculty and students who took the survey.

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