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Divergent Views: Teacher and Professor Perceptions About Pre-College Factors That Influence College Science Success

Interview data from secondary and postsecondary science instructors explored their in depth views on preparing students for college science. Professors expressed a high level of consensus concerning two factors: general student skills and mathematics preparation. Teachers, who expressed lower levels of consensus, did agree on the importance of mathematics, but also highlighted a variety of factors that promote active pedagogy in the classroom as well as the importance of technology, textbooks, other materials, and assessments. Given this divergence, the authors explored the research supporting the value of these factors as well as highlighted possible strategies for narrowing the gap.

Introduction

Transitioning from secondary to post-secondary education is a daunting challenge for many students. Preparing them for this transition is an equally daunting task for their teachers. A recent report from Stanford University, *Betraying the College Dream*, points out that success in high school is a necessary yet insufficient step (Venezia, Kirst, & Antonio, 2003). The authors identify a serious disconnect between high school and college coursework and standards, and the lack of any system to facilitate a successful transition. In science education, the finding of a "disconnect" is not new. Studies conducted more than ten years ago reported important differences between the focus of high school teachers and expectations of college professors regarding student preparation (Razali & Yager, 1994; Shumba & Glass, 1994).

It is increasingly important to re-address this transition because students, parents, and even high school teachers are unaware of what is expected of students entering college science. The risk is another generation of students entering college with insufficient science preparation to support their success and persistence. Adding to this concern is the decline in the average scores of high school seniors between 1996 and 2000, which may indicate that the preparation of high school seniors is declining rather than improving (National Science Board, 2006). Of more particular concern is the challenge the United States faces in maintaining its competitive edge in science research at the international level. The task of preparing future scientists for work in the US has become more difficult as the number of non-citizens in American universities and research institutions has decreased. Daunting visa restrictions for foreign scientists and science students have limited the pool of available researchers who can work in the US in recent years (Simoncelli & Stanley, 2005; Glanz,

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2003). In addition, the National Science Foundation reports, "the number of native-born science and engineering (S&E) graduates entering the workforce is likely to decline unless the Nation intervenes to improve its success in educating S&E students" (National Science Board, 2003, p. 1). Thus, high school and university science teaching can play a key role in increasing students' interest, performance, and future success thereby re-invigorating the future of science professions in the US.

In this study, we examine in detail the range of perspectives of 20 high school science teachers and 22 professors of introductory science at post-secondary institutions regarding the factors they consider most important in facilitating the transition from high school science to college science study. Our purpose was to identify the factors that secondary and post-secondary science instructors consider essential in supporting student transition to post-secondary science, and to explore any trends that emerged from these views. To that end, we identify specific areas where teacher and professor views are similar, as well as dissimilar, and compare our results with earlier reported research (Razali & Yager, 1994; Shumba & Glass, 1994). Our study investigates how factors identified by both science instructors and the research literature impact student success in university science. Lastly, we offer suggestions for narrowing the gap in viewpoints and facilitating high school-college transitions.

Background

The issue of how to prepare students for college work has been addressed many times over the years, beginning with foundational work by the Committee of Ten at the end of the 19th century. At that conference, members "unanimously declare[d] that every subject which is taught at all in a secondary school should be taught in the same way and to the same extent to every pupil so long as he pursues it, no matter what the probable destination of the pupil may be, or at what point his education is to cease" (National Education Association, 1893, p. 17). Even though this view has evolved to meet contemporary issues in education, curricular reform still focuses on the content and the skills needed to prepare students for success in college.

Professors, who often face introductory level classes that are an order of magnitude larger than those found in high schools, know less about individual students and have fewer pedagogical alternatives to choose from due to large class sizes or limited knowledge of pedagogy.

A century later, the Association of American Universities addressed the preparedness gap in their project, Standards for Success. Their report, *Understanding University Success* (Conley, 2003), makes explicit the skills students need to succeed in college. To succeed in the natural sciences, the report stresses the importance of possessing basic knowledge of concepts and knowing how to: think about science; ask questions and solve problems; read, write, and communicate; and be oriented towards learning. It also highlights the importance of mathematics skills. The purpose of *Understanding University Success*, as well as *Betraying the College Dream* (Venezia et al., 2003), is to address students' lack of preparation for post-secondary work, which also increases their risk of not completing college programs. This resonates with findings of the American Council on Education (2003); nearly a third of all students enrolled in U.S. post-secondary institutions between 1995 and 2001 dropped out. Although *Understanding University Success* highlights skills necessary for success, the report does not address pedagogical strategies teachers might use to develop such skills, nor does it evaluate which skills or combinations of skills contribute most to students' college success.

Smaller-scale studies over the past 20 years have focused on identifying specific skills that correlate with success in post-secondary science (Alters, 1995; Gifford & Harpole, 1986; Hart & Cottle, 1993; Long, McLaughlin, & Bloom, 1986; Sadler & Tai, 2001; Tai, Sadler, & Loehr, 2005; Tai, Sadler, & Mintzes, 2006). However, whether results from these studies are used in classroom decisions often remain the prerogative of high school teachers. They typically make instructional decisions based on personal beliefs about what is effective pedagogy (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Professors, who often face introductory level classes that are an order of magnitude larger than those found in high schools, know less about individual students and have fewer pedagogical alternatives to choose from due to large class sizes or limited knowledge of pedagogy. In such situations the default pedagogical technique is to simply communicate to students what they need to know rather than use more effective, albeit difficult to employ, pedagogy that actually helps students learn the material.

Over a decade ago researchers in two studies documented the divergence in views between professors and high school teachers regarding both broad and specific student preparation factors. Razali and Yager (1994) found that chemistry professors rated students' personal attributes as more important for success in college science than specific content-related knowledge or skills. Those personal attributes included study skills, math and English proficiency, interest/motivation, inquisitiveness, perseverance, focus, and science aptitude. The content-related knowledge and skills considered in the study included specific chemistry concepts (e.g. density, ideal gases, moles, types of reactions, etc.) and skills needed (e.g. determining mass, balancing equations, interpreting periodic table information, etc.). High school chemistry teachers, on the other hand, rated subject matter knowledge and skills as more important than personal attributes. In a related study, college faculty responsible for coordinating introductory chemistry reported that high school graduates were insufficiently prepared for college, especially in broad areas such as "mathematical skills," "science process skills," and "higher-order thinking" (Shumba & Glass, 1994, p. 388). These studies highlight the difference between the content-related focus of high school science teachers in preparing students for college science and the general-skills expectations of college science professors.

The goal of our research was to highlight the views from both sides where teaching philosophies have evolved to meet very different demands, and the situation unfortunately continues to maintain the gap that students experience. Specifically, we sought to address the following questions: How do high school teachers view the challenge of preparing students for further study in the sciences? Do professors agree? Is there more agreement than there was a decade or a century ago? Lastly, are these beliefs supported by research?

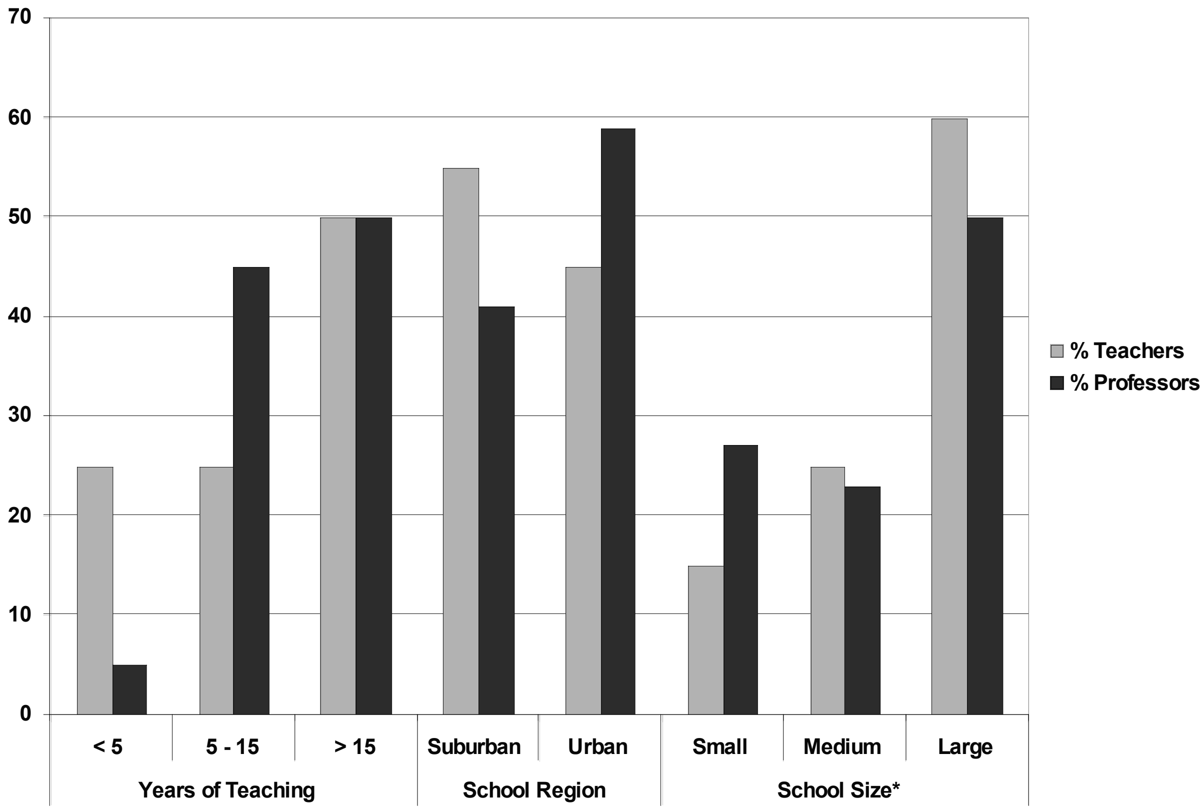
Surprisingly, professors placed more emphasis on the affective domain such as relationship building and encouragement.

Methodology

Twenty high school science teachers and 22 university science professors were contacted by phone or email, and all agreed to participate in interviews. The sample was based on three criteria: (a) they had at least three years of teaching experience or were identified as exemplary by their colleagues (in the case of high school teachers), (b) they regularly taught high school science or introductory university science courses (biology, chemistry, physics, or general science) that served as foundation courses for college-level sciences, and (c) they were from diverse schools based on urban/suburban location and size. Such a sample offered a diverse spectrum of strategies used in high schools of differing demographics and size to prepare students for post-secondary study. In addition, this sample included experienced teachers and professors who consistently taught introductory science courses because they would presumably be familiar with appropriate pedagogies for teaching introductory science and would have distilled from those pedagogies a subset that they believed useful in preparing students for science at the college level. Figure 1 compares the distribution of teachers and professors in the sample based on the criteria.

Although the teachers and professors selected taught at a cross-section of different sized schools, most of our sample taught at large high schools or universities since the majority of U.S. students attend large schools. In 2003, 63% of secondary school students attended large high schools, 23% attended medium sized schools, and 14% attended small schools (Snyder, Tan, & Hoffman, 2006). Similarly, 60% of the high school teachers in our sample taught at large schools, 25% at medium sized schools, and 15% at small schools. In 2003, 54% of university students attended large degree-granting institutions, 20% attended medium sized institutions, and 26% attended small institutions (Snyder, Tan, & Hoffman, 2006). In our sample, 50% of the professors taught at large, 23% at medium, and 27% at small institutions. These three size categories roughly match the "large, medium, and small" classifications in the "size and setting" category in the latest iteration of the Carnegie Classification of Higher Education (2005), which were not explicit in the earlier edition (Carnegie, 2000). It is also worth noting that in the latest iteration of the Carnegie Classifications, new categories such as "enrollment profile" and "undergraduate profile," were not considered in this study. As these categories reflect aspects of the university's mission, they may also

Figure 1. Percentage of teachers and professors by experience level, school region, and school size.
*Small, medium, and large high schools are respectively less than 500, between 500 and 1000, and more than 1000 students in size. Small, medium, and large colleges/universities are respectively less than 5000, between 5000 and 10000, and more than 10000 students in size.



lead to professor views that are unique to these categories.

Our methodology differed from that employed in earlier studies. Shumba and Glass (1994) administered questionnaires to faculty at large colleges with enrollments over 10,000. Razali and Yager (1994) reached a greater diversity of schools through random sampling, but like Shumba and Glass (1994), they also used questionnaires. Our goal was to develop a richer picture of teacher and professor views through interviews and analyze in detail the beliefs held by experienced science instructors at a range of different sized schools. Thus, teachers and professors that we interviewed were part of a purposeful sample. They were based in cities in California, Florida, and Massachusetts.

Associates who could identify different school settings and administrators within each school initiated the teacher selection process. These contacts, who were current or former principals, identified teachers they felt were hard working, dedicated individuals, who cared about their students' preparation for college. Beyond their high level of professionalism, teachers could differ philosophically because we did not try to pool them across any particular domain or context. The teachers taught in a variety of upper and lower income neighborhoods, and in suburban and urban schools. Their teaching experience ranged from three to over 30 years. They had all taught college-preparatory high school courses in biology, chemistry, physics, or another science sub-discipline. Seven were teaching or had taught AP courses and two were teaching or had taught in the International Baccalaureate program.

On average, each interview lasted 60 minutes. Interviews were tape-recorded and took place in each teacher's classroom. The principal question for all teachers was: Which of your teaching strategies or techniques do you feel is critical in helping your college-bound students succeed in an introductory college level science course? Teachers were encouraged to focus only on those students they assumed were going to college, and that the interview's only goal was to identify teaching styles or techniques they used to prepare those students whom they felt would pursue science at postsecondary institutions. The interviewer recorded strategies, and then summarized the factors that emerged. As the interview took place in the teacher's classroom the interviewer could also ask about the role of models, student projects, lab materials, etc. in view. The teachers reviewed the list to ensure that their ideas were accurately represented and to ensure that they had not overlooked any strategy they considered essential for the success of those students who would continue to study science at the postsecondary level.

No professor mentioned the need to give students more decision-making power over their own learning.

The 22 university professors, recruited to consider the same challenge given to high school teachers, were identified through college and university web sites. The schools selected were all 4-year degree-granting colleges and universities. All professors recruited taught introductory science (biology, chemistry, or physics) at their college/university every year or every other year. The professors were initially contacted by email, and interviews were subsequently scheduled by email or phone. These interviews were also open-ended, ranging from 45 to 90 minutes, and were tape-recorded. Because we asked professors to comment on teaching strategies they believed high school teachers should employ (and not necessarily their own strategies), we developed open-ended prompt questions to help professors reflect on the preparation their students needed and on what high school experiences they believed were necessary.

As professors had less knowledge of their students (usually due to large class sizes), the interviews began with prompt questions to help professors focus on the difference between successful and less successful students in their courses, and the role that preparation played in supporting student success.

- In your introductory course, what are the differences between an "A" student and a "C" student? (As some professors had never considered their students' characteristics and preparation before, this question actually helped them begin to reflect on such issues. Thinking about the differences between students helped them later to reflect on what they thought was important for students to learn in high school science.)
- How useful do you think students' high school science preparation is to their success in your introductory science course? Why? In what ways?

The above questions were accompanied with many probes to help professors focus on high school preparation. Additional questions that also helped professors identify specific strategies within high school and high school science that they believed would contribute to success in their course included:

- I'm a high school science teacher and I need your help to better prepare my students for your college course. How should I structure my course? What are the most important things for me to teach? How should I teach those things?
- I'm a high school student and you are my mentor. What should I concentrate on in high school in order to be successful in your course once I get to university? What things should I include in my high school experience?

(Note that these questions are not meant to probe what professors believe *actually happens* in high school but what they believe *shoul*d happen in high school to prepare students for college science. Accompanying probes focused professors on specific content and teaching strategies.)

Teacher and professor interviews were later analyzed to extract all factors that they believed would influence a student's college science performance. Once these were extracted, the researchers met to discuss each factor and its definition, and to generate a common list of factors mentioned by the teachers and professors. This included discussion of the nuances of factors and decisions of whether new factors needed to be created when existing teacher factors did not suitably map the results of the professor interviews. The taped interviews were also used to refine the characterization of each factor in order to ensure accurate coding and comparison. Several iterations of analyzing and comparing of factors from both groups resulted in two lists of factors identified by the teachers and professors—"detailed factors" and "broad factors."

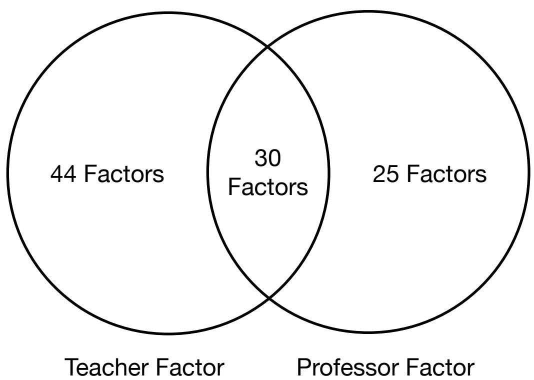
This process of identifying categories and links between categories, and then testing the strength of these links in an iterative fashion follows the "grounded theory" approach for generating plausible theories about qualitative data (Charmaz, 1983; Dey, 1999; Glaser & Strauss, 1967; Glaser, 1992; Strauss & Corbin, 1990). Thus, the first iteration of analyses produced categories that reflect highly specific views of teachers and professors regarding what they believe influences student success in college science (e.g., a particular strategy of instruction, specific content that is a necessary part of the curriculum, etc.). These detailed factors (described in further detail in the next section) emerged as a result of comparing and contrasting teacher and professor views. In later iterations, the detailed factors were further narrowed to a series of "broad factors." These factors represent a further layer of analysis moving from specific strategies to general categories that capture larger themes representing a broader view of the content within the specific factors. The broad factors generalize the complexity of curricular choices that teachers and professors view as important for high school students' future science success.

Results

Detailed Factors: A detailed view of teacher and professor views

The teacher group identified 74 different specific factors, while the professor group identified roughly a third fewer (i.e., a total of 55 factors). There were 30 factors in common between both groups and 69 factors unique to one group. Thus, there were 99 unique factors overall (see Figure 2 and Table 1). Of the 74 factors that teachers identified as important in ensuring success in college science, 19 factors (26%) were mentioned by as few as two or as many as six teachers. The remaining factors (74%) appear only once and are thus unique to individual teachers. No two teachers shared more than two detailed factors except in one case. Teachers, on average, generated six factors each. On the professor list, 44 factors (80%) of 55 were shared by as few as two or as many as 16 professors and 11 factors (20%) appear only once and are thus unique to individual professors.

Figure 2. Venn diagram of unique and shared teacher and professor factors.



Professors, on average, generated nine factors each.

Among factors important to teachers was "multiple exposures," a factor similar to "multiple sensory approach" and "multiple problems and contexts." Each of these factors focused on techniques that teachers used to revisit an element of their teaching. In the case of "multiple exposures." teachers generally agreed that students would benefit from exploring course material through different approaches (e.g., video, the internet, library work, additional demonstrations, or revisiting an old theme from a new perspective). Those teachers using a "multiple sensory approach" highlighted the importance of the other senses as a way to reinforce course material through sensorimotor activities.

Some teachers highlighted "specialized curricula" as important. We noted six specialized curricula or programs: the International Baccalaureate curriculum, Modeling Physics, a thematic and spiral curriculum, a job-related curriculum integrating community issues, business and science, and the academy model (e.g., California Partnership Academies—an academic program for small learning communities that includes active business involvement).

Other factors that two or three teachers mentioned as important were: "discussions," "student-designed labs," "use of tech software," and "regular feedback." Although we doubt the teachers in this study would disagree with the factors their peers identified, we did not ask them to comment or revaluate their own ideas based on the views of their peers. Thus, the focus remained on factors that teachers individually thought were important.

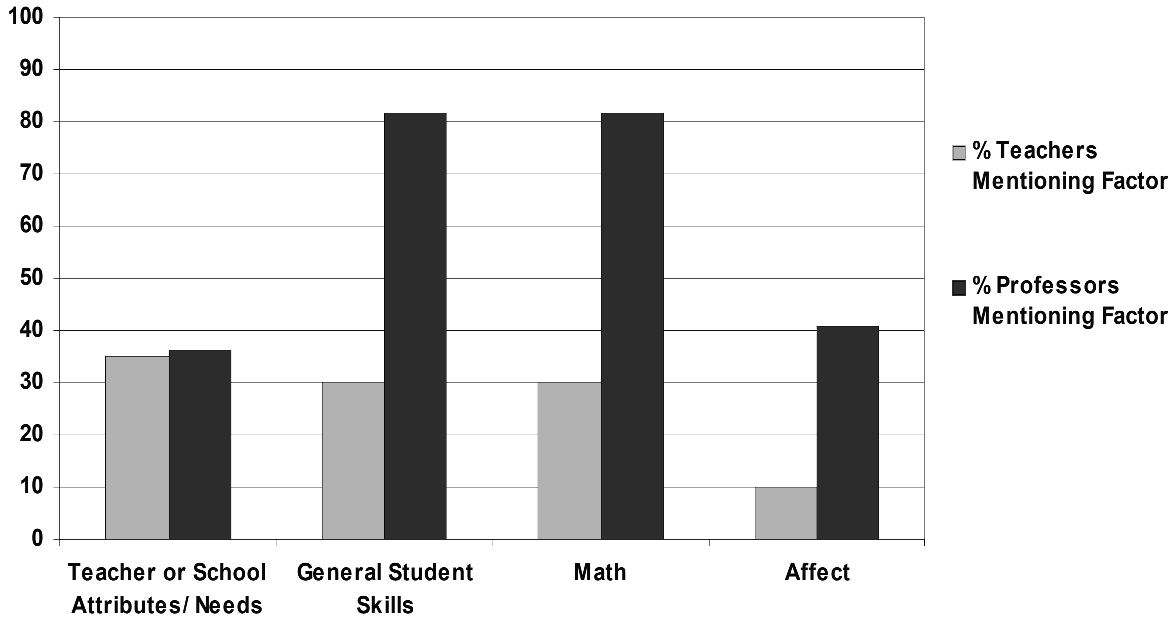
Additional factors important to professors were "develop thinking skills," "avoid memorization," "conceptual learning," "improve study skills," "math in context," "cooperative learning," and "real-life contexts." Two of these refer to general student skills ("develop thinking skills" and "improve study skills"). Professors expressed a need for students to start thinking both in and out of school rather than engaging in rote activities and to engage in productive and efficient study habits. Two of the additional factors refer to learning requirements in high school science ("avoid memorization" and "conceptual learning") and two others

Table 1. Sixteen broad factors obtained from ninety-nine detailed factors

	Condensed Broad Factors	Detailed Factors	
General Factors	Teacher or School Attributes/Needs	Block scheduling (T) Business-like environment (T) Class size & number of preparations (T) Improve teacher competence (S) Maintain personal expertise in discipline (T) Outside help (P)	Teacher collaboration (T) Teacher enthusiasm (P) Teaching staff mirrors diversity in community (T) Time to prepare (T) Well-read teachers (S)
	General Student Skills	Develop thinking skills (S) Improve reading skills (S) Improve study skills (S) Improve writing skills (P) Learning to outline problems (T)	Scaffolded note taking (T) Self-teaching (P) Time-management skills (T) Work ethic (P)
	Mathematics	Estimation without calculator (P) Math in context (P)	Math proficiency (S)
	Affect	Enrich teacher-student relationship (S) Parent encouragement (P)	Role models (P) Teacher encouragement (P)
HS Science Pedagogy/Content	Labs	Confirmatory labs (T) Dissection labs (T) High-tech labs (S) Inquiry-based labs (S) Lab-based curriculum (T)	Paradigm labs (T) Problem-centered labs (T) *Reality labs (simple, practical outcomes) (S) Student-designed labs (T)
	Student Autonomy and Voice	Independent projects (S) Oral presentations (T)	Student-designed labs (T) Students share curriculum responsibility (T)
	Demonstrations	Thematic demos (S)	
	Technology	High-tech labs (S)	Use tech software (S)
	Textbook and Materials	Content relevant material (T) Equipment available to all (T)	Teacher-designed materials (lecture, but no textbooks) (T) Use textbooks (S)
	Real-Life and Interdisciplinary Contexts	Cultivate internships (T) Establish HS-Univ. relationship (T) Explore job connections (S) Humanize science (P) Integrating the sciences (T)	Mentoring w/ professionals (S) *Outside experience (field trips, meet scientists) (P) Real-life contexts (P) *Reality labs (simple, practical outcomes) (S) Service-related projects (T)
	Interactive Learning	Cascade learning (T) Competitions (T) Cooperative learning (S)	Discussions (S) Role playing (T)
	Repeated Use of Topic	*Mental framework (evolutionary, approximation models, etc.) (P) Multiple exposures (T)	Multiple opportunities to work with “data sets” (T) Multiple opportunities w/ tools of science (S)
	Variation within Topic	Alternative representation (S) Hierarchical questions (S)	Multiple problems & Contexts (S) Multiple sensory approach (T)
	Other Pedagogical Techniques	Curriculum should mirror college (T) Integration of Reading (T) Interpreting experiments (T) Mimic scientists (P) No jargon teaching (P) Provide structure (S)	Science is cool (P) Specialized curricula (S) Student journals (T) Supervise student work (no homework) (T) *Teach specific topic (e.g. evolution, genetics) (P) Unit analysis approach (T)
	Learning Requirements	Avoid memorization (S) Breadth over Depth (P) Conceptual learning (P)	Depth over Breadth (S) Increase rigor (S) Memorize basic concepts (S)
	Assessment	Cumulative tests (T) Essay exams (T) Maintain high accountability (T) Multiple assessments (T) Peer evaluation (T)	Pop quizzes (S) Regular feedback (S) Self-assessment (P) Variety of Tests (T)

(T) – Teacher factor (P) – Professor factor (S) – Shared factor *More than one factor joined

Figure 3. Percentage of teachers and professors mentioning general factors.



to creating links with people and the everyday world ("cooperative learning" and "real-life contexts"). The last often cited factor was the need for students to develop further sophistication and proficiency in mathematics with the capability of applying these skills to problems in many different contexts ("math in context"). In the following section, we condense the detailed factors into a narrower sub-set of broad factors, which will then be compared across teachers and professors.

Broad Factors: Narrowing the views

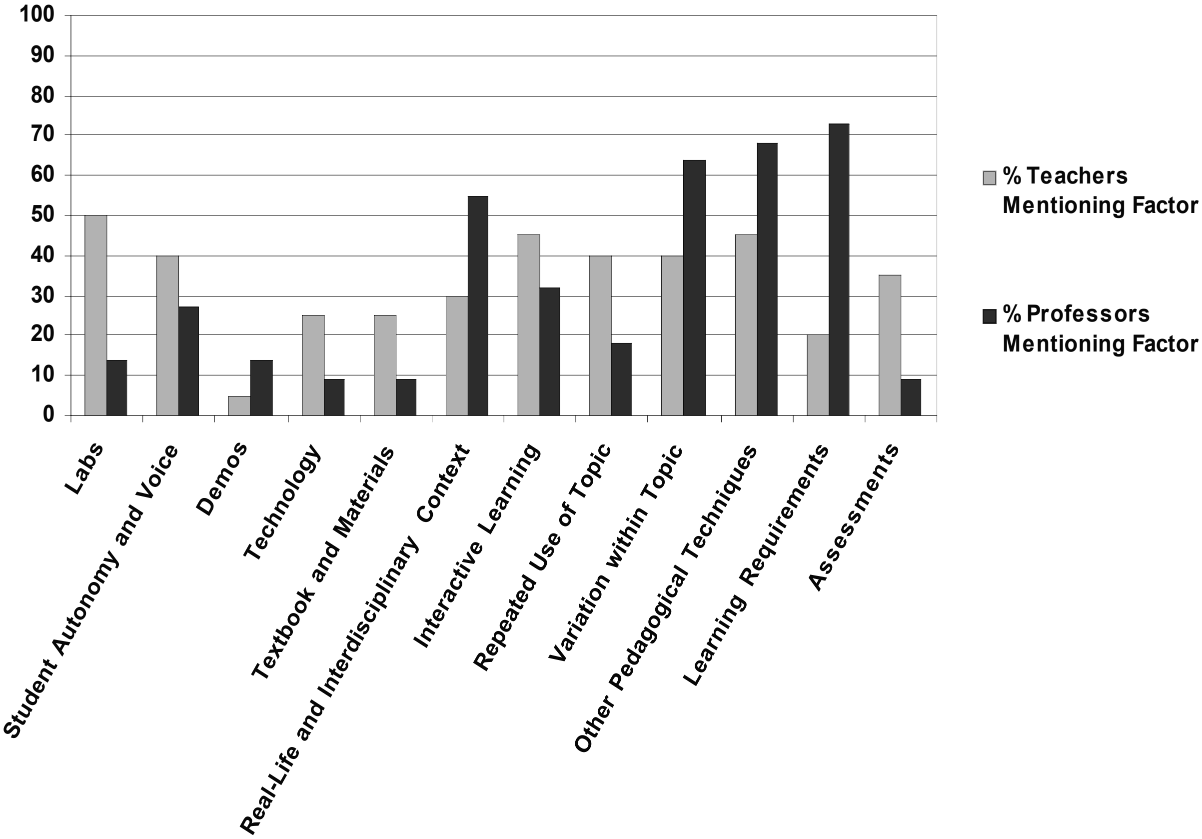
The 99 *detailed* factors identified by teachers and professors were organized into16 *broad* factors that encompass each detailed factor (Table 1). The broad factors were further organized as either "*General*" (e.g. General Student Skills) or more specifically focused on "*High School Pedagogy*/*Content*" (e.g. Labs). Of the nearly 100 detailed factors, only the ones related to laboratory work appear in more than one of the broad factor groupings (because diverse strategies can be used to accomplish laboratory work). For example, the detailed factor "reality labs" was included in two broad factors groupings "labs" and "real-life and interdisciplinary context," thus highlighting how one factor could encompass two broader concerns.

Once the detailed factors were condensed into broader categories, a more focused comparison between teachers and professors could be completed. Figure 3 shows the percentage of teachers and professors mentioning the four general broad factors—"teacher or school attributes/needs," "general student skill," "math," and "affect." Figure 4 shows the percentage of teachers and professors mentioning the twelve high school science-related broad factors—"labs," "student voice and autonomy," etc.

Among the four general factors (Table 1), three were cited more often by professors than teachers– "general student skill," "math," and "affect" (Figure 3). Teachers and professors mentioned in equal proportion "teacher or school attributes/needs." Among the high school science factors (Figure 4), four were mentioned more frequently by professors than by teachers—"real-life and interdisciplinary context," "variation within topic," "other pedagogical techniques," and "learning requirements." Seven were mentioned more frequently by teachers than by professors—"labs," "student autonomy and voice," "technology," "textbook and materials," "interactive learning," "repeated use of topic," and "assessment." The factor mentioned least by both groups was "demonstrations." These comparisons are summarized in Table 2.

Examination of Figure 4 shows that labs were the most prominently mentioned factor among teachers; however, little consensus emerged as to what constituted effective laboratory experiences (Table 1). Half of the teachers interviewed pointed out that conducting labs constituted

Figure 4. Percentage of teachers and professors mentioning high school science pedagogy or content factors.



an important skill or component of their curriculum. These teachers viewed laboratory experiences as a necessary and explicit method for verifying knowledge that students needed to understand, and agreed that labs were essential for students who wanted to be successful in college science courses. However, when the detailed factors relating to laboratory work are examined, we find that most of the teachers diverged in their views about the nature of effective laboratory experiences such as how they should be conducted, where within the syllabus they should be scheduled, the types of equipment that should be used, and who should be responsible for designing the laboratory activities. The only exception to this divergence was a smaller group of four teachers who agreed that laboratory investigations should be designed by students to be effective. In addition to laboratory work, teachers also emphasized other factors ("student autonomy and voice" and "interactive learning") that encourage students to assume active roles in class. Teachers were also comparatively more concerned with what materials to use, how to reinforce content throughout the year, and employing appropriate assessments ("textbook and materials," "technology," "repeated use of topic," "assessments").

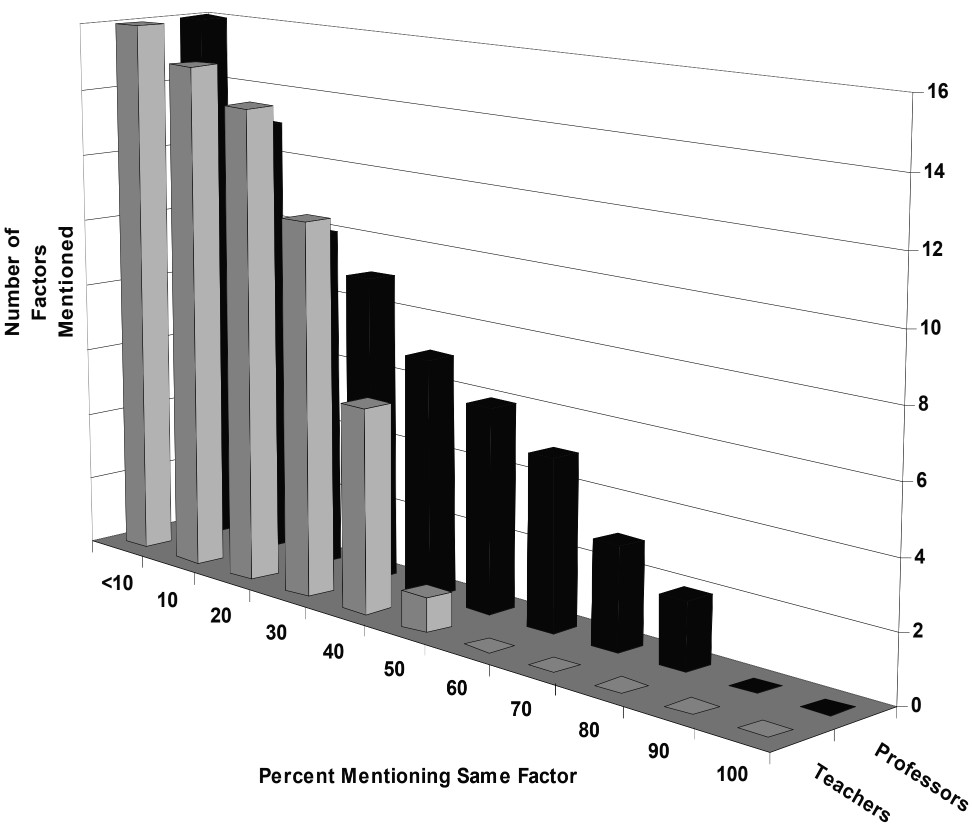
Professors, on the other hand, were less concerned with motivating students to participate actively in science class and expressed greater concern for skills and learning processes that should be mastered ("general student skills," "math," "learning requirements") and identified several pedagogical techniques that might help students develop a more complete mastery of topics being taught ("variation within topic," "other pedagogical techniques"). However, several professors did claim that making science relevant to students' lives ("real-life and interdisciplinary contexts") was necessary.

Figure 5 shows the distribution of agreement among teachers and professors across the 16 broad factors identified. For example, there was at least 10% agreement among the teachers for 15 of the 16 broad factors and at least 10% agreement among professors for 13 of the 16 factors. Similarly, no factors had at least 60% agreement among teachers but five

Table 2. Frequency comparison of the sixteen broad factors mentioned by professors and teachers.

Percent of Teachers Identifying a Broad Factor	Percent of Professors Identifying a Broad Factor: 0 to 10%	11 to 20%	21 to 30%	31 to 40%	More than 40%
0 to 10%		• Demos			• Affect
11 to 20%					• Learning Requirements
21 to 30%	• Technology • Textbook and Materials				• General Student Skills • Math • Real-Life and Interdisciplinary Context
31 to 40%	• Assessments	• Repeated Use of Topic	• Student Autonomy and Voice	• Teacher or School Attributes/ Needs	• Variation within Topic
More than 40%		• Labs		• Interactive Learning	• Other Pedagogical Techniques

Figure 5. Level of agreement between teacher and professor groups on broad factors.



factors had at least 60% agreement among professors. Note that the narrower spread for teachers in Figure 5 suggests a lower level of general agreement than that of professors.

Discussion

The most striking finding is the vastly greater number of unique teacher responses compared to professor responses. However, there is a far greater level of overlap within the professor group than that observed in the teacher group despite the fact that professors, on average, identified more factors each than did teachers. Table 3 lists the top ten shared factors within the teacher group and the top ten shared factors within the professor group. The arrows indicate three instances where the factors overlap between the two groups: "math proficiency," "alternative representation" (i.e., challenging students to demonstrate their understanding through representations differing from their instructors' representations. For example, students might develop essays, concept maps, Venn diagrams, 3-D models, drawings, etc.) and "multiple problems and contexts." All three factors stand out as important for both groups, although decidedly more important to professors. Clearly, mathematics preparation, using new representations to demonstrate understanding, and presenting problems that require students to revisit the concept introduced through some variation of the original problem are important aspects of college preparation in the view of both teachers and professors.

Teachers are often trained and encouraged to use diverse teaching strategies that convey the material effectively to different types of learners. This is embodied in the teachers' pedagogical content knowledge (PCK). PCK can be defined as the combination of content and pedagogy that is distinctly the province of teachers. It encompasses

Table 3. Top ten detailed factors cited by the teacher group and professor group, ranked by percent agreement within groups.

Top Detailed Teacher Factors	Percent Citing Factor	Top Detailed Professor Factors	Percent Citing Factor
Math proficiency	30	Math proficiency	73
Multiple exposures	30	Develop thinking skills	45
Specialized curricula	25	Avoid memorization	41
Alternative representation	20	Conceptual learning	41
Discussions	20	Multiple problems & contexts	41
Multiple sensory approach	20	Improve study skills	36
Student-designed labs	20	Math in context	36
Use tech software	20	Alternative representation	32
Multiple problems & contexts	20	Cooperative learning	32
Regular feedback	20	Real-life contexts	32

From the data in Table 1, note that the detailed teacher factors are more specific than those that professors identified regarding interventions that they believed students required. This focus accounts for the greater number of unique factors mentioned by the teachers; the cited factors are examples of specific techniques the teachers favor and/or use (such as "scaffolded note taking"). On the other hand, professors frequently suggested general factors such as "develop thinking skills" and "conceptual learning," even when probed for more specific strategies. The fewer unique factors generated by professors is understandable given they are not usually trained in pedagogy, and they lack specific knowledge about either high school science curricula or the numerous pedagogical techniques high school teachers might use.

not only knowledge of the subject matter but also how to teach it in such a way that learning difficulties and misconceptions are overcome and the material is effectively communicated (Shulman, 1986; Van Driel, Verloop, & de Vos, 1998). While science professors may be experts in the content, teaching large sections is not conducive to trying diverse teaching strategies.

Professors demonstrated a high level of consensus for certain broad factors and an equally low consensus level for others. However, teachers had a consistent consensus level (between 20 and 50%) for all of the broad factors but two. The generally higher consensus level among the professors is not a surprising finding for several reasons. First, high school science teachers not only prepare students who will enroll in college science programs but also teach and engage students who will not. Professors teach groups of students with similar academic goals (e.g. introductory science for non-majors, introductory science for science majors). Thus, techniques employed by teachers vary due to the fact that they are trying to achieve more than the goal of preparing students for college science.

Second, most high school science teachers have received some formal preparation in pedagogy appropriate to science teaching. They are also more likely to have encountered science education research in their preparatory programs. However, science education researchers generally agree that teachers still do not make sufficient use of the research (White, 1998; Costa, Marques, & Kempa, 2000; Tillotson, 2000), which might have contributed to the lack of teacher consensus in this study as to what constitutes effective pedagogy. University science professors in our study, on the other hand, had no training in pedagogy. In fact, examination of the professors' courses revealed that all the professors in this study use lecturing as their primary pedagogical technique!

Given that professors have little knowledge of pedagogy used in high school, their viewpoints reflected mostly what they believed to be the broad goals of high school science and they did not offer as many techniques that high school science teachers could employ. Their primary desire was for high school to equip students with a high level of mathematics proficiency, and higher-order thinking and study skills. Two professors commented:

> *I actually think that students would be better served in high school if they had courses in logical reasoning and forget the science. … Most students for example are unable to use anything that they learned in their mathematics courses in any other context. You know, they can do algebra as algebra, or geometry as geometry, but they can't do it if you ask them about population sizes. They have virtually no ability to visualize concepts pictorially or even to analyze … in most high school courses, science courses are words, words, words, words, words.*

> *I'm not sure it's [high school chemistry] particularly useful and the reason is that we emphasize deep understanding as opposed to just manipulative skills. We find that students haven't developed that understanding and if anything, the more successful they've been, the more difficulty they have in the early part of the course because they tend to think they understand all the material and its only after the first few exams when their scores aren't nearly as good that they start to take them more seriously.*

Teachers also believed that factors such as mathematics preparation and student skills were important to success in college. One chemistry teacher commented:

> *All of science depends on math. I would say that if my students needed to learn anything to be successful in science, it would be math. They need to understand the math.*

This view was echoed in many of the interviews with high school teachers. An almost equivalent percentage of the teachers and professors thought that the general factor, "teacher or school attributes/needs," was important (e.g. better teacher preparation, more school resources and support mechanisms) (Table 2). Surprisingly, professors placed more emphasis on the affective domain such as relationship building and encouragement. Two professors remarked:

> *Your high school science experience really shapes your outlook on science in such a fundamental way that it can make all the difference … many of them [students] say, 'oh I had a great high school physics teacher' or 'I had such a lousy physics teacher'. Almost none of them say that it was a mediocre experience. It was just very very strong one way or the other and usually that determines very strongly how they react to my class.*

> *They [students] don't sense a set of people, aspirations, hopes, ambitions, y'know, concerns. It's just this body of fact. Well that's no place you wanna live. You don't wanna live inside a set of numbers, right? You wanna live inside a set of human relationships. So, if there is no way of gaining access to that, students basically find it to be an alien off-putting kind of domain … They look at science in that same way.*

In terms of specific techniques that high school science should employ to help students succeed in college science, professors had far fewer suggestions to offer than did teachers. Professors mainly stressed learning requirements that focus on conceptual understanding and depth rather than broad coverage, using real-life contexts and variation in presenting the material and in the types and quantity of problems that students need to solve.

> *I don't personally think that they come with any significantly positive set of things learned, concepts learned. So I would rather have a course cover a very narrow spectrum of the field and get into it deeply enough to force logical thinking than to try to encompass everything that's in a freshman biology book.*

> *I also think that students nowadays need a little bit more experience with the real world … I mean they don't know very much about the real world at all.*

> *They [students] learn best by doing it themselves. There is absolutely no question.*

Teachers, on the other hand, stressed the importance of laboratory activities, student autonomy, interactive learning, and repeated and varied topic use (Figure 4). The first three of these suggest an emphasis on students participating actively in their learning. This implies a possible preference for student-centered pedagogy. A physical science teacher, from a school that had forged industry and science connections, commented:

> *We are teaching students to become active thinkers and members of the community. They need to understand how science fits into their lives and how they and the science they are learning fit into their community. For example, biotechnology is a big industry in our community, but given the range of ability of students in my class their ability to take advantage of this option will vary. Students need to see ways in which they can best exploit this opportunity.*

Although professors encouraged independent thinking and techniques such as cooperative learning, the implication is that even these strategies should be directed within a structured curriculum. No professor mentioned the need to give students more decision-making power over their own learning. Perhaps professors do not strongly encourage this type of learning because student input is not considered when formulating college science curricula and most college science courses follow a highly structured format comprised of lectures, tutorials, laboratory sessions, and exams. Giving students curricular choice in high school might not prepare them for such structured courses in college. However, it may be the best method for engaging students who would not normally be engaged in science learning. High school science teachers must balance this important additional goal with the goal of preparing students for college science. One inner-city biology teacher stressed:

> *I have students from all walks of life. Some will go to college, and some will not graduate. But this year while I have them all, I have to try to find a way to connect with them all, to keep them engaged. I need to focus on their lives and the role biology has in helping them understand the choices they make as well as the more abstract science that I know some of my students will need in college.*

In comparing this work with studies from a decade ago, we discovered that there is little change in the "disconnect" between high school science and college science.

Is there more agreement than a decade ago?

In comparing this work with studies from a decade ago, we discovered that there is little change in the "disconnect" between high school science and college science. Consistent with Razali and Yager (1994), we found that college professors consider general student attributes more valuable than the actual science content knowledge; especially because professors in our study believed that high school content is usually not imparted at a deep enough level to support conceptual understanding or development of analytic science skills. Similarly, Shumba and Glass (1994) reported that "good study skills and habits" and "emphasis on thinking skills" were the two most highly rated characteristics for success in college chemistry by coordinators of college freshman chemistry – "Science content can come later" (p. 389). Teachers in our study emphasized practical classroom strategies to communicate science concepts. This finding is consistent with Razali and Yager's (1994) findings as teachers in their study professed the importance of students attaining specific science knowledge over more general skills; teachers interviewed in our study highlighted techniques they considered important to help students gain that knowledge. However, a new finding in our study is that teachers emphasized techniques that actively involve students in their own learning (e.g. curriculum decision-making, working with others on activities, conducting projects of their own choosing). A chemistry teacher from a large suburban school commented:

> *Students are becoming more critical of their educational experience. They want to know why they are doing the work, and I think they should know. The world is becoming a complex work environment where students need to see ways to contribute as well as why their contribution is important.*

There was less professor emphasis on strategies of that type. Shumba and Glass (1994) reported that "emphasis on personal needs and interests of students" was rated by college chemistry coordinators as one of the least important priorities in high school science (p. 387). Although this view was generally supported by professors in our study, a shift was noted in the importance given to the affective domain such as enriching the relationship between teacher and student, teacher encouragement, and parent encouragement. These affective factors have become increasingly important with waning student interest in science and science-related professions (National Science Board, 2000; Tobias, 1990). Entering and becoming part of a science class is like a 'cultural border crossing' – a crossing from the subculture of their family, peers, and world outside class, to one of school science (Aikenhead, 1996; Brickhouse, Lowery & Schultz, 2000; Costa 1995). This border crossing becomes an easier transition for students whose family subculture is coherent with science culture or is at least encouraging and positive toward science study. Epstein and Salinas (2004), proponents for organizing family, community, and school partnerships, write, "To learn at high levels, all students need the guidance and support of their teachers, families, and others in the community" (p. 17).

By far, the most consistent finding between a decade ago and today is the importance of mathematics preparation to college science success. A faculty comment reported in Shumba and Glass's (1994) study was, "While basic information in the sciences is important, math through spherical trig. and elementary calculus and application of those skills through word problems is more important" (p. 389). A decade later, a faculty viewpoint quoted in *Understanding University Success* resonates, "Basic math skills are, quite possibly, the most important set of skills for students to have mastered coming into a freshman science course. They need to understand why equations work and what each equation says about the physical world…" (Conley, 2003, p. 40). Indeed, our results also reveal that both high school science teachers and introductory college science professors agree that mathematics proficiency is a factor essential for success in college science.

Are the views supported by research?

Thus far, the discussion of results has focused on the literature to compare the views in this study with those reported a decade ago. We now turn to a discussion of the research literature that either supports or contradicts the views expressed by teachers and professors. In other words, do the high school factors that teachers and professors view as important to college science success *actually* help in college science according to the research literature?

By far, the most consistent finding between a decade ago and today is the importance of mathematics preparation to college science success.

In terms of general student ability, Sadler and Tai (2001) found that high school grade point average (GPA) was a significant predictor ($p<0.01$) of success in college physics. It is arguable that the GPA may reflect a general skill set since high school physics grades, calculus enrollment, and even socio-economic status control variables (i.e., parental education, location and type of high school attended) were included separately in their analytic model. This general skill set may include their skills in studying, analytic thinking, time management, etc. Thus, this result loosely supports the teacher and professors' beliefs that this general skill set ("thinking skills," "reading skills," "study skills," etc.; see Table 1) influences college performance. The specific teacher/professor belief that reading and writing skills are important is further supported by the reported positive relationship of students' SAT verbal scores and their last high school English grades with their introductory college science performance (Tai, Sadler, & Loehr, 2005; Tai, Sadler, & Mintzes, 2006).

The strongest belief held and shared by teachers and professors in this study is also the factor most strongly supported by research—the importance of mathematics proficiency. Previous studies have found that high mathematics SAT scores (Long, McLaughlin, & Bloom, 1986; Tai et al., 2005), calculus enrollment (Sadler & Tai, 2001; Tai et al., 2005), and high school mathematics grades (Alters, 1995; Gifford & Harpole, 1986; Hart & Cottle, 1993; Tai et al., 2005) are all associated with higher performance in introductory college science. In fact, in many of these studies, mathematics proficiency is the strongest predictor of success in college science.

Within the affective domain, Tai et al. (2005) found that students who reported that they were not encouraged to take science by anyone were likely to perform slightly better ($p<0.05$) in college chemistry than those who reported receiving encouragement. If this generally holds true, then the professors' belief that parental and teacher encouragement plays a large part in college success is not supported. However, Cavallo, Potter, & Rozman (2004) found that affect in terms of self-efficacy or belief in one's ability in a particular subject was a strong predictor of college physics achievement for both male and female students. Perhaps, encouragement is not in itself conducive to better future performance but encouragement insofar as it increases students' belief in their own abilities is.

The high school pedagogy most highly supported by the teachers was the use of laboratory activities. However, research results seem much less supportive of the influence of laboratory experiences on later college science performance. The number of laboratory experiments performed in high school science has been found to be negatively related to college science performance, in that the more laboratories a student performed in high school science, the worse the student was likely to perform in the corresponding introductory college science class (Sadler & Tai, 2001; Tai et al., 2006). Furthermore, while reading and discussing laboratory activities a day before performing them in high school science classes is negatively related to college science performance, the relationship is positive when high school laboratory experiences are repeated for understanding (Tai et al., 2005) or they address students' beliefs about the world (Tai et al., 2006). These results might support the teachers' belief in the importance of certain types of laboratory activities, such as "reality labs," but laboratory work in general does not seem to be as effective as the teachers believed. Clearly the effectiveness of labs in preparing students for college science is highly dependent on how the lab is carried out and what its purpose is. Compared to labs, the teachers in this study were far less favorable toward demonstrations. This lack of enthusiasm is consistent with results of research reporting that discussion after demonstrations (Sadler and Tai, 2001) and the number of demonstrations (Tai et al., 2006) are both negatively related to future success in introductory college science. The number of student-designed projects in high school science has also been found to be negatively related to success in traditional college science courses (Tai et al., 2005; Tai et al., 2006). Projects that provide students autonomy in designing their own project and an opportunity to express their own interests may, however, play important roles in motivating and engaging students more substantively. Teachers in our study favored such pedagogy more than did professors. Perhaps this highlights a significant mismatch in views. Introductory college science courses that encourage students to express their own ideas as part of the coursework are virtually non-existent.

The K-16 enterprise is one collaborative venture that can generate additional educational leverage by allowing the whole community to align their educational goals to benefit all students, not only those transitioning from secondary to postsecondary institutions.

Within the "textbook and materials" broad factor, one sub-factor mentioned by teachers alone, was supported by the early Sadler and Tai (2001) study. Several teachers reported that it was important to use their own instructional materials rather than following the textbook. This view is supported by research findings reported by Sadler and Tai (2001); students who reported less textbook use in high school physics did better in introductory college physics than their counterparts who reported more textbook usage.

The "real-life contexts" broad factor contains many sub-factors identified by teachers and professors that relate to incorporating connections to scientific careers or even to scientific professionals themselves within the high school science curriculum. These connections might lead students to better understand their career options and the fruitfulness of scientific endeavors. In support, Tai et al. (2005) found that students whose families believed that science supports a better career did significantly better ($p<0.01$) than students who did not come from such families. Perhaps this motivating belief stemming from scientific work connections could be stimulated not only through students' families but also through high school science curricula.

The broad factor mentioned most by teachers after laboratories was "interactive learning," which included the sub-factors: "cascade learning," "competitions," "cooperative learning," "discussions," and "role playing." The importance of activities where students have opportunities to interact on class work is again supported by the findings of Tai et al.'s (2005); the more time students reported spending on individual work (i.e., by themselves) in high school chemistry class, the worse they performed in introductory college chemistry.

Aspects of the broad factors "repeated topic use" and "variation within topic" were also found in the results of research studies on college performance. In terms of "repeated topic use," Tai et al. (2006) found that having key concepts studied longer or recurring throughout the year in high school science was strongly related to better college science performance. In terms of "variation within topic," Sadler and Tai (2001) found that having physics teachers who explained problems in several different ways was related to better performance in college physics. In addition, Tai et al. (2006) found that the frequency with which students were required to analyze pictures and illustrations in high school science, rather than simply solving written problems, was positively related ($p<0.001$) to their college science performance.

Finally, learning requirements within high school science courses have been found to be an important predictor of college science performance. Specifically, high school science courses focusing on understanding the material/concepts, rather than simply memorizing factual information, have been found to positively predict college science performance (Tai et al., 2005; Tai et al., 2006). In addition, courses limiting coverage of material (i.e., focus on depth rather than breadth) were also related to better student performance in college (Sadler & Tai, 2001). These results are consistent with the beliefs reported by teachers and professors in our study that memorization should be avoided and that depth is preferred to breadth.

Conclusion

We feel, as do Venezia, Kirst, and Antonio (2003), that a mechanism is necessary to bring secondary and postsecondary educators and institutions together with the goal of facilitating the transition between high school and college and reforming science education cooperatively at both levels. Educators and administrators from both groups need to understand the issues they face independently and collectively. Upon this foundation, they should articulate learning goals they are trying to attain. If both groups are only superficially aware of each other's goals, as well as the means used to attain these goals, then it is not reasonable to expect that high schools will effectively prepare students to succeed in a postsecondary environment.

Establishing a system that brings educators together is occurring in communities that are adopting a K-16 perspective. Both the University of Missouri-Colombia and the University of Texas at Arlington have created collaborative groups focusing on the continuum of study that begins in kindergarten and ends with degrees from those universities (University of Texas, 2002; University of Missouri, 2006a). This focus facilitates the alignment of goals across the continuum and allows instructors to be more effective in selecting the means to reach goals that everyone can be confident belong to the entire community.

Finally, the lack of focus on pedagogical strategies in many postsecondary science departments continues to favor an approach that addresses some problems (i.e., delivering via lecture information to large numbers of students), while creating or sustaining existing problems (i.e., poor understanding of the content and high attrition rates). Although educational research has a long and established history of concentrating on university level instruction and science instruction in particular (e.g., Levinson-Rose & Menges, 1981; Arons, 1990; Hestenes, 1998; Gabel, D. 1999; McDermott & Redish, 1999; Redish, 2003), the teaching beliefs and practices of professors in this study were largely unaffected by this or similar research. However, universities are paying attention to instructional techniques used by professors, at least at the undergraduate level (as evidenced by the increase in science education research within science departments focused on improving introductory science coursework). Additionally, universities such as McGill University and the University of Missouri-Columbia have created positions that focus on improving science education within the university (McGill, 2005; University of Missouri-Columbia, 2006b). Nonetheless, greater support and accountability at the university level can help professors more readily recognize the importance of enhancing their teaching techniques.

The sustained and visible support for pedagogy by universities not only highlights an important educational issue, it is a message that will resonate throughout the education community. This common agenda can act as a platform that encourages universities to re-evaluate its role in education. The K-16 enterprise is one collaborative venture that can generate additional educational leverage by allowing the whole community to align their educational goals to benefit all students, not only those transitioning from secondary to postsecondary institutions.

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