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Chemistry Professors' Perceptions of Undergraduate Learning

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Chemistry Professors' Perceptions of Undergraduate Learning

Abstract
This study investigated 27 chemistry professors' perceptions of learning in undergraduate education and their suggestions for adopting an inquiry-based pedagogical approach to teaching and learning. Semistructured interviews revealed that two thirds of participants perceived undergraduate learning in traditional ways such as the acquisition of basic facts in a discipline. One fifth perceived undergraduate education as an active way of learning, specifically taking advantage of existing opportunities for students to engage in research experiences. Four professors described learning as a balance between the roles undertaken by students and instructors, namely students becoming more involved in the process of asking questions. Suggestions on how to bring teaching and research closer together in undergraduate education included (a) seeking research opportunities, (b) providing authentic learning environments, (c) capturing students' curiosity, and (d) varying teaching methods. Although some statements did not provide a specific practical suggestion about how to achieve an inquiry-based pedagogical approach in higher education, a beginning of change was observed among chemistry professors' perceptions of students' roles toward one of active learning.

Cette étude analyse les perceptions de 27 professeurs de chimie sur l'apprentissage dans l'enseignement au niveau du premier cycle ainsi que leurs suggestions pour adopter une approche pédagogique d'apprentissage fondé sur l'exploration. Des entrevues semistructurées ont révélé que les deux-tiers des participants percevaient l'apprentissage au niveau du premier cycle de manière traditionnelle, tel que l'acquisition de connaissances de base dans une discipline. Un cinquième d'entre eux percevaient l'enseignement au niveau du premier cycle comme une manière active d'apprendre, spécifiquement en profitant des opportunités existantes qui permettent aux étudiants de participer à des expériences de recherche. Quatre professeurs ont décrit l'apprentissage comme un équilibre entre les rôles joués par les étudiants et ceux joués par les instructeurs, c'est-à-dire les situations où les étudiants sont davantage impliqués dans le processus qui consiste à poser des questions. Des suggestions pour savoir comment rapprocher l'enseignement et la recherche dans l'enseignement au niveau du premier cycle comprennent : (a) rechercher des occasions de recherche, (b) fournir des environnements d'apprentissage authentique, (c) éveiller la curiosité des étudiants, et (d) varier les méthodes d'enseignement. Bien que certaines déclarations n'aient pas fourni de suggestions pratiques spécifiques sur la manière d'en arriver à une approche pédagogique d'apprentissage fondé sur l'exploration dans l'enseignement supérieur, un début de changement a été observé parmi les perceptions des professeurs de chimie sur les rôles des étudiants vers un apprentissage actif.

Keywords
higher education, inquiry, chemistry, teaching, learning

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A continuing challenge for education lies in the responsibilities of teachers and students to engage in learning so that they develop the skills, knowledge, and dispositions they need to successfully function in today's society and that of the future. There is no one recipe for success, but there are pedagogical approaches that transform educational practice so that students can move beyond being passive recipients of knowledge to become knowledge builders, capable of creative and innovative solutions to problems.

While traditional instruction includes lectures and mandatory classroom lab activities, inquiry-based pedagogical approaches engage participants in similar social learning with interactive activities, but with students posing and solving their own problems and exchanging roles among themselves and with the teacher. This, in turn, impacts how learning is structured in the classroom. Moving students, however, beyond initial curiosity to a path of regular inquiry is important to inquiry-based learning. In this process, educators play an important role in many ways: finding creative ways to bringing about students' ideas based on interest, modeling how to contribute and expand on those ideas, formulating a question, carrying out an investigation of one's ideas or hypotheses, and providing opportunities for students to engage in sustained inquiry of their own. The teacher's role is further emphasized as he or she needs to establish a classroom culture in which ideas take flight and students come in groups to discuss each other's learning, as well as understanding their own ideas and approaches to questions and problems through hearing others' perspectives. A common concern for educators new to inquiry is how to teach with an inquiry approach when there are so many curriculum expectations to address with short timelines. By steering the conversation toward the "big ideas" of a particular concept rather than the narrower definitions and specific expectations, students' questions often lead to, and might even exceed, overall curriculum expectations, thus reaching across conventional boundaries between discrete subject areas. The present study explores these phenomena in the experiences of chemistry professors and their perceptions of learning in undergraduate education about how an inquiry-based approach might be initiated.

Literature Review

Bringing Inquiry into the Classroom

Enhancing and strengthening a positive, mutually beneficial relationship between teaching and research as inquiry is a core part of the identity of many academics (McLean & Barker, 2004). However, the nature, frequency, and strength of this link have often been limited to anecdotal rationalization with a recurring criticism that undergraduate education is perceived as less of a priority when compared to research and professional activities (Bok, 2006; Finkelstein, 2001). In a social-constructivist framework, "Education as inquiry provides an opportunity to explore collaboratively topics of personal and social interest using the perspectives offered by others as well as by various knowledge domains" (Harste, 2001, p. 1). Therefore, defining inquiry simply as a set of student-led activities with the teacher acting as facilitator to a more elaborated list of tasks involving the teacher, student, and curriculum could create challenges to the actual and successful practice of inquiry-based instruction (Crawford, 2007). This is especially important because practicing a discipline (emulating authentic learning processes) and practicing discipline-based activities (such as interactive and hands-on classroom activities) are not the same thing (Chichekian, Hua, & Shore, 2013).

If teaching and research are to be linked in practice and not just in theory or rhetorically, specific instructional strategies need to be implemented spanning from an inquiry or research-based pedagogy such as being able to critically assess knowledge, exercising rational judgments, and evaluating evidence (Healey, 2005; Justice, Rice, & Warry, 2009; Justice, Rice, Warry, & Laurie, 2007). Robertson and Bond (2005) identified three ways professors can bring inquiry into their classroom: sharing their research findings, modeling learning through the research process, and actively engaging students in research. Institutional commitment also plays a key role in the development of strong relationships between teaching and research. How researchers view research and scholarship affects how they conceptualize the nature of student learning. For example, individual variables related to acceptance of, or resistance to, change have sturdy qualities and, therefore, pose a barrier to introducing new pedagogies within an existing program or curriculum at both the organizational and individual levels (Justice, Rice, & Warry, 2009). Understanding the special nature of resistance to change within universities and the contextual challenges these pose is key to successful pedagogical innovation.

Barriers to Achieving a Balance among Research, Teaching, and Learning

An undergraduate research experience is marked not only by collaboration between or among students and faculty but also by the critical role that professors play in creating and fostering a nurturing learning environment. If teachers are to act as mentors and models to students, then active learning as well as critical and creative thinking need to be encouraged from the outset. In this context, research- or inquiry-based approaches are especially appropriate because they directly facilitate linking the scholarly and teaching mandates of universities and colleges.

Since Hattie and Marsh's (1996) landmark publication, several studies have identified mediating variables that affect the relationships between teaching and research. In addition to teachers' beliefs, mediators that have had effects on academics' experience of the relationship between teaching and research include conceptions of research (Coate, Barnett, & Williams, 2001; Prosser, Martin, Trigwell, Ramsden, & Lueckenhausen, 2005) and of learning (McLean & Barker, 2004). For example, pressures to compartmentalize teaching and research, management strategies of academic staff time, and competition for funding have shaped the ways in which teaching and research can have an influence on each other. Also, the ways academics understood their subject matter (atomistic vs. holistic) influenced their views of teaching: information transmission and teacher-focused ways compared to more conceptual change and student-focused ways. As relationships between professors and students evolve, it is imperative to adhere to what Hu, Scheuch, Schwartz, Gayles, and Li (2008) stated—that "the definition of 'teaching' should be broadened to include research and creative activities so as to reflect a more contemporary and proactive perspective on the totality of our educational endeavors" (p. 182). Weaving and enhancing research, teaching, and learning, however, could be perceived as threatening to faculty members whose teaching practices rely heavily on discipline-based content and a lecture-based approach (Justice et al., 2009). The latter was also echoed in a report from the National Research Council (Kober, 2015) entitled "Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering" in which evidence pointed to the way undergraduate science courses were traditionally taught—through lectures and reading assignments, note-taking and memorization, and laboratories with detailed instructions as well as a predetermined and anticipated result.

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Similarly, the need to enhance undergraduate education using inquiry-based instructional practices as described in the Boyer Report (1990) stressed that faculty members and students needed to re-evaluate their roles and relationships based on four kinds of scholarship—discovery, application, integration, and teaching. The Report called for a new model of undergraduate education in which students' learning experiences are integrated into the research and scholarship of universities and described a desired situation in which students do function as researchers, scholars, or inquirers, and steps that instructors and institutions can take to create such a learning situation. However, the follow-up reports from the Boyer Commission (2001) chronicled slow and limited adaptation of these teaching approaches. What have been the barriers? Henderson and Dancy (2011) stated that the the biggest barrier to using more research-based practices is the limited knowledge about how to effectively apply the currently available and tested high quality, research-based instructional strategies and curriculum development. Other common challenges as identified by Kober (2015) included those relating to time involved in learning about new strategies and redesigning courses (especially when teaching is often viewed as a lesser priority, and one that is not promoted by the institutional reward structure), doubts about ensuring that students are taught important content, and stress about students' reactions to an unfamiliar teaching method and the impact on student course evaluations. Such concerns are especially relevant because other studies have noted that there is marked, context-dependent variation in how the research-teaching nexus is experienced (Brew, 2003). Student histories, institutional support, and other demands on time and effort also affect what is done, possible, or perceived as possible.

To understand how chemistry professors' views of pedagogical actions impact undergraduate research and their perceptions of undergraduate learning, we asked:

1. What are chemistry professors' perceptions of learning in undergraduate education?
2. What pedagogical actions do chemistry professors perceive as building blocks toward bringing teaching and research closer together in undergraduate education so as to move toward building a culture of inquirers?

Method

This study investigated chemistry professors' perceptions of learning as a reference point a quarter-century later based on an earlier report about teaching in the same chemistry department that revealed a widespread transmission mode of teaching (Shore, Pinker, & Bates, 1990). In Shore et al. (1990), lectures were the predominant form of teaching method for 15 of 18 (83%) chemistry professors, especially when the class size was over 30 or when students were undergraduates. Several references pointed to lectures as the preferred teaching tool and although good lectures can engage and captivate an audience, they remain an indirect method of involving the learner in the process of knowledge production, similar to reading the travel blogs or traveller notes of an experienced globetrotter.

Also, a study from Hua and Shore (2013), using the same sample as the one in our study, revealed six ways in which chemistry professors' engagement in research activities strengthened their teaching practice, including student interest, subject-matter currency, research examples, ways of thinking (e.g., how research helps them appreciate differences between "what is" and "what we know" and demonstrate "how [we] know this is true"), contextualization, and explanation (e.g., how concepts, principles, and facts are organized in chemistry). Professors' belief that active engagement through research helped them provide better explanations of the

material to improve student understanding represented a promising base from which to conduct the current study and re-evaluate professors' perceptions of undergraduate learning. The present research received Research Ethics Board approval from our university before data were collected.

Sample and Data

Participants were 27 chemistry professors (five females and 22 males) from a Canadian research-oriented university and represented 90% of the departmental professoriate and 87% of the undergraduate instructors. The majority of the instruction in the chemistry department took the form of lectures combined with mandatory lab activities as the main venue to experience hands-on activities in the 55 courses offered at the undergraduate level. In the year we collected this data, the core mission of undergraduate teaching in the department of chemistry was to undergo changes to offer innovative learning environments (e.g., fully renovated teaching labs) based on the reception of multimillion dollar federal funding. Instructional spaces featured a unique design that optimized students' ability to work in a collaborative manner with research quality laboratory infrastructure and instrumentation.

Data included semistructured interviews of 30 to 60 minutes and were conducted individually in each participant's office. Ten questions with follow-ups addressed professors' instructional practices, their achievement goals and learning environment they set for their students, as well as their perceptions regarding the link between teaching and research (see the Appendix for the full list of interview questions). This study explored the link between chemistry professors' perceptions of undergraduate learning and of the pedagogical actions that bring research and teaching closer together in the classroom.

Replies were transcribed verbatim and data remained unsegmented in order to identify the main ideas in the participants' replies. We relied primarily on open-coding content analysis (Creswell, 2003) in which the first step was to extract tentative common concepts by identifying words, ideas, events, and actions in the data that could be grouped by similarities. This iterative process continued until responses from all 27 participants were analyzed. Concepts were then compared one against each other in a process of constant comparison to verify the occurrence of any similarities and then grouped together under a more inclusive category. Next, two independent raters coded the data. One rater, who had no previous connection to this project, was given only general directions and identically assigned 75% of all statements to identified categories on the first attempt. A second rater, a doctoral student in our research team, independently assigned 84% of all statements to categories. After the first round of coding, slight adjustments were made to help refine and delimit the boundaries of each category. The second round of coding was conducted with the revised categories. In subsequent iterations, these categories were characterized and demarcated, expanded or reduced, until a 100% level of inter-rater agreement was obtained.

Results

The first part of our results describes chemistry professors' views of learning in undergraduate education (e.g., active, passive) accompanied by statements illustrating their views. The second half defines pedagogical actions that chemistry professors perceive as building blocks toward bringing teaching and research closer together in the classroom.

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Chemistry Professors' Perceptions of Learning in Undergraduate Education

Emerging perceptions of undergraduate learning were described in traditional ways of learning (18 of 27; 67%), active learning (5 of 27; 19%), and a balance between traditional and active ways of learning (4 of 27; 15%). The following bulleted points are examples of illustrative statements (with the participant's identification number in parentheses) from professors who perceived undergraduate learning from a traditional perspective:

- Knowing the basics (nine professors, 33%)
    - Students must know the basics to acquire the tools and learn the alphabet in any domain. (P03)
- Receiving information (six professors, 22%)
    - At the introductory course level, you have to be a receiver of information because otherwise you are not going to get anywhere . . . It has to start with information. (P24)
- Teaching paradigms (seven professors, 25%)
    - That's the approach. We lecture to them. (P22)
- Classroom climate (seven professors, 25%)
    - Sometimes when I ask the questions, there's a dead silence; it's like, OK, the point has been missed. (P27)
- Time limitations (seven professors, 25%)
    - Always a certain amount of education or certain things that can be done because you are faced with one key factor: There's a real time limit. (P04)
- Culture of the society (four professors, 15%)
    - Over the years that I have taught, I've seen more and more students want to be presented information because their culture in general has things where information is presented and it's presented rapidly. (P20)

If faculty members' perceptions regarding undergraduate learning differed, it was mostly (a) in their explicit articulation regarding changes reflected in the culture of undergraduate society and (b) in their understanding regarding similarities or differences between receiving and assimilating information. For example, some professors made statements such as "undergraduates are in a position in which they need to receive information and to assimilate," (P02) which suggested that they perceived learning in a traditional, lecture-based format in which students take on passive roles.

Other professors made statements such as "they are not receivers of information, they are assimilators of information," (P21) which we interpreted as learning being perceived in a more critical stance. We classified professors' views of undergraduate learning as an active process if their responses referred to the positive effects of research experience and mandatory laboratory experiments on learning, autonomous learning, asking questions, and making links. The following bulleted points are examples of illustrative statements from professors who perceived undergraduate learning as a more dynamic interaction. The last two statements are from professors who described their perceptions as a balance between traditional and active ways of learning.

- Research experience (one professor, 4%)
    - Honors students have to do an undergraduate research project; they have to go out and do the research and you try to mentor them a little bit and help them along the way. So they do get a taste of doing research. (P05)
- Laboratory experiments (one professor, 4%)
    - They do laboratories and they have to learn and become knowledgeable how to use the equipment. Not just use it but also understand how it works. (P05)
- Autonomous learning (one professor, 4%)
    - I think that undergraduate education should be an active learning process. If you want to receive information, go get a book, read about it. There's no reason you have to sit in my class. And most of the undergraduate students told me they don't go to class. They read a book and they go to the exam, and they pass the exam and get a grade. (P15)
- Shift in the undergraduate culture (one professor, 4%)
    - I think that culture maybe was there a few years ago, not anymore. It's changing. I find more and more kids are now vocal, they challenge. All you need to do basically is channel the energy in the right direction. I don't really think they're receivers. (P23)
- Eureka moments (one professor, 4%)
    - The more you know, the simpler things get. When you put the idea across, and they start to see the simplicity, every so often a light goes on with some of the students, and that's what you want to achieve. (P05)
- Roles of students and teacher (one professor, 4%)
    - Yes, in the sense that we are there to teach and they are there to be taught. No, when I see some interaction at least for some of them, they want to know more, they are eager to learn, they are not just passively learning what they have to know to get a good mark at the end of the term. (P08)
- Vision of chemistry education (one professor, 4%)
    - We're training students to be graduate researchers and scholars. We're not training them to be professional chemists. (P11; "professional chemist" here referred to the employment of chemistry graduates such as in the chemical industry, and not to pharmacy)

Overall, our results provided signs of progress compared to the findings from Chichekian et al. (2013) regarding moving more toward a culture of inquirers. Despite two-thirds of the chemistry department still preferring a transmission mode as a teaching method compared to 83% 25 years ago, our results are indicative of progress that is more aligned with the department's agenda regarding instructional development and the implementation of active learning spaces.

Bringing Teaching and Research Closer Together in Undergraduate Education

When asked about suggestions on how to foster a culture of inquirers as the next generation of undergraduates, all chemistry professors provided examples (illustrated below as verbatim excerpts from the interview transcript) of how they perceived supporting students to become thoughtful, motivated, collaborative and innovative learners capable of engaging in their own inquiries and thriving in a world of constant change.

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Suggestions from professors who viewed learning from a traditional perspective.

- Seeking research opportunities
  - The undergraduates who have passed through my research lab seem to have an appreciation for what happens in a modern research context. It's totally different from the labs that you take as part of your undergraduate courses. (P27)
- Making learning authentic
  - Motivate them with examples. The link between everyday life and what they learn in class is not direct. (P01)
- Facilitating transitions
  - We take information receivers and we try to train them to be information assimilators and information users. That's the transition that we're trying to do for undergraduate teaching. (P21)
- Providing smaller classes
  - Smaller class sizes help, certainly at the lower levels. (P16)
- Sharing information
  - Having the WebCT system in which some students would post questions and others would really go and answer, and many times with very, very good answers. Sort of in a team work. (P12)
- Sharing teacher and student roles
  - I'd like to see it encouraged to where there's more ownership of duties on both sides. And, again, I think it's about asking questions and, if you can get more people into the lab, you could do that. (P20)
- Varying teaching methods
  - It's a combination of things or a set of exercises that they'll learn something from. And it's good to combine that with a more open-ended exercise. (P04)
- Teaching thinking skills
  - They should learn how to think, solve problems. . . . What happens when the instrument breaks? What are we going to do? (P25)

Suggestions from professors who viewed undergraduates as active learners.

- Capturing students' curiosity
  - Give them enough scientific information to say, well I want to learn a little bit more about this. (P23)
- Encouraging research involvement
  - I encourage my students to volunteer in a research lab. (P15)

Suggestions from professors who viewed undergraduate education as a balance of traditional and active ways of learning.

- Providing an authentic learning environment
  - Get them involved with the hands-on nature of inquiry, that's where much of the learning occurs. (P07)
- Clarifying goal-setting
  - So you have to make sure it is clearly stated what you really want to teach and what you really want to tell them, and to tell a story. (P08)

- Modifying the classroom context
    - Standards and expectations, how we set up the environment for them, how we set up the whole learning-teaching process. (P14)
- Teacher beliefs
    - If you think that they can deliver something challenging and difficult, and so they will. If you assume that these students, they cannot do anything, they will not do anything. (P14)

Despite differences in professors' views of undergraduate learning, they expressed parallel ideas on how to integrate research in the classroom to facilitate and encourage undergraduates in adopting an inquiry-based approach to learning. We also observed a continuum between the pedagogical actions suggested by professors who viewed undergraduates differently (see Table 1).

Table 1
Shared Suggestions of Pedagogical Actions for Integrating Research within Teaching and Learning in Undergraduate Education

Suggestions of pedagogical actions	Professors who viewed undergraduates as		
	traditional learners	as active learners	a balance between traditional and active learners
Modifying Teaching Methods	"People have to recognize to ask the questions. The Socratic method of trying to ask a question to somebody and put them on the spot could be fostered from the earliest times." (P20)		"So you have to make sure it's clearly stated what you really want to teach and what you really want to tell them, and to tell a story." (P07)
Research Experience	"I hire students every summer to work in my lab." (P17)	"I encourage my students to volunteer in a research lab." (P13)	
Authentic Learning	"You can go in the lab and make real compounds that are useful and interesting." (P18)		"Get them involved with the hands on nature of inquiry, that's where much of the learning occurs." (P09)

(continued)

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Suggestions of pedagogical actions	Professors who viewed undergraduates as		
	traditional learners	as active learners	a balance between traditional and active learners
Participating in the Honors Program	"Our honors students get a taste of real research." (P18)	"Honors students have to do an undergraduate research project; they have to go out and do the research and you try to mentor them a little bit and help them along the way. So they do get a taste of doing research." (P05)	
Involvement in Summer Research Projects	"We have research opportunities in the summer and in the senior year." (P18)	"The other thing which we do is we have summer research projects, but it's just the research experience." (P05)	
Conducting Lab Experiments	"It's the lab . . . doing new things. Doing things that don't necessarily have a recipe for them." (P04)	"They do laboratories and they have to learn and become knowledgeable how to use the equipment. Not just use it but also understand how it works." (P05)	

Although some descriptions were directed at the institutional level, such as smaller class sizes, especially in the first year of undergraduate education, and sharing of information through an online platform, all professors were especially focused on educating a new generation of scholar-teachers in chemistry and did not appear to take into account the wide variety of other students with other goals and trajectories who study university chemistry. Chemistry professors encouraged students to seek research opportunities by joining a research lab, taking on a summer research project, or participating in an honors program in which they complete a research-based project. This pedagogical approach extends beyond having a lecture more closely linked to the laboratory experience; professors were keen to receive volunteers in their research labs and perceived such an opportunity to provide them with just enough scientific information to capture students' curiosity. Within such a context, they viewed their own role as facilitators of transitions—from learning about research in classrooms through open-ended exercises to participating in an authentic research laboratory. They also described the diversification of roles undertaken by students and teachers to help develop critical thinking skills.

Discussion

The purpose of the present study was to describe: (a) how chemistry professors perceived learning in undergraduate education and (b) how to bring teaching and research closer together in undergraduate classrooms. The perceptions held by our sample of chemistry professors regarding undergraduate learning did not focus exclusively on instructional practices associated with research activities as advocated by the Boyer (1990, 2001) report but rather reflected their own experiences and commitment to improving instruction. Their statements regarding teaching and research echoed the literature regarding enhancing the quality of undergraduate education and research experiences (Brew, 2003, 2010; Friedman et al., 2010; Hu, Kuh, & Gayles, 2007; Hu et al., 2008; Justice et al., 2009; National Research Council, 2012). If a difference existed among professors, it lay in a fine but relevant point of distinction, namely, how they perceived the transition of a student from simply receiving information to one who is taking a more proactive approach to his or her learning. Those who perceived undergraduates as passive learners articulated this explicitly, and those who did not see them as passive reported personal experiences reflecting changes they have observed in the undergraduate culture. Additionally, many of the pedagogical actions that professors described focused on honors programs and limited existing opportunities for laboratory affiliations focused more on training future potential chemists. Between 5% and 10% of the university's students in basic level undergraduate chemistry courses are in honors chemistry or majors in a given year. Students from other science majors, nursing, engineering, and education also take introductory and intermediate undergraduate chemistry courses, rather than higher-level courses that enroll mostly chemistry specialists. Therefore, these suggestions are only partially useful because they only target a specific and relatively smaller number of students.

Despite their perspectives about undergraduate learning, our study echoed similar findings from Chichekian et al. (2013) because professors largely referred either to contextual contributors such as programs, laboratories, research groups, or to explanations through fine-tuning teaching by asking questions or being clear about goals. Professors generally connect their teaching to their research in ways that point to examples of initiatives (e.g., keeping course content up-to-date or modeling for students the intellectual curiosity and critical thinking that characterize good research) and this might usefully be addressed in instructional improvement efforts, professional development, and departmental conversation on how to promote the research-teaching connection in undergraduate education. Chemistry professors in this study made no suggestions about how to initiate a fundamental or substantial change in how courses and teaching could be organized or planned. For example, Aulls, Kaur Magon, and Shore (2015) showed that education professors who did take an inquiry-based approach to their teaching planned their courses long in advance of the semester, but then adjusted classes as they were enacted, based on what occurred in previous classes. Instructors who did not take an inquiry approach were much more likely to plan classes closer to their scheduled dates and also to rely more heavily on a single midterm and final exam for evaluation.

Although the present results provided partial support for the nexus of research and teaching, some limitations should be taken in consideration when interpreting the findings. The study was conducted in a specific context, particularly in terms of a single discipline's departmental culture, and institutional and wider frameworks. The practical relevance of the results, however, is not entirely local because there are other chemistry departments in similar situations, and instructors in other disciplines may recognize similarities to their own situations.

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However, broader generalizations would require that comparable studies be conducted in different disciplines, institutions, and instructional traditions. This study also included only a one-sided exploration, namely professors' perceptions about the integration of research in teaching. In a pedagogical context favoring inquiry-driven learning, teaching should also have an effect on research practices and these potential effects merit further exploration.

Implications for Practice

Results from this study point to descriptions that provide beginning signs that being an active researcher contributes to effective undergraduate teaching. Perhaps an important early step needs to be to convince professors that their choice of instructional practices does have a major impact on student learning and on achieving a closer knit between teaching and research. In addition, taking small steps in this direction provides good and useful beginnings that build confidence that students can be trusted to be effective partners in constructing their own understanding. It is important to change perceptions about the perceived priority to fill students with information before exposing them to research is a challenge for both professors and students. Some instructors are ingenious about incorporating interactive features and prompting contemplative moments. By the same token, nonlecture approaches do not automatically achieve active learning—although they may increase the likelihood of it happening. Information about the nature of students enrolled in undergraduate courses might prompt openness to a range of initiatives that extend beyond direct engagement in classroom lab activities toward smaller, progressive steps such as independent projects or meaningful contributions to research labs and our results have begun tracing the beginnings of such a continuum.

Achieving the goal of undergraduate students becoming or functioning as inquirers requires fundamental or substantial revision in how courses are conceived and delivered. The interviewed chemistry professors' perceptions of undergraduate teaching and learning were relevant opening steps to further study the extent of professors' preparedness, motivation, and self-efficacy to teach by bringing in research into the undergraduate classrooms. Another key question related to this topic might be: What are the variables (including instructor perceptions, competing demands, and aversion to change) that might account for the continued reliance by some on the traditional lecture as the sole or central modality for teaching? Although there are some data supporting how faculty link their research and teaching more effectively by introducing students to the research process, further studies are required to demonstrate if and how faculty effectively integrate the content of their research into their classes.

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Appendix
Interview Questions

1. What are your preferred teaching methods in each of the courses that you've taught?

    a) Can you explain your reasons?
    b) Can you describe an example of a typical class?
    c) Can you give me an example of how you prepared for a typical class?
    d) What goals and objectives did you set for the students to achieve in each course that you taught?
    e) How well did your students achieve these goals?

2. What else (besides the course content) is important to communicate to chemistry students? (i.e., soft skills, ideas, approaches to problem solving)

    a) How do you do this?
    b) How well did your students achieve these goals?

3. What do you consider to be ideal teaching conditions?

    a) If you were to teach under ideal teaching conditions, what teaching methods would you use?
    b) What teaching methods would be most suitable to the following groups of students?

        i. freshmen
        ii. non-specialized undergrad
        iii. specializing undergraduates [honors],
        iv. master's students
        v. doctoral students

4. Can you give me an example of how you draw connections between what you already know and new things that you learn in your field?

    a) Can you give me an example of how you help your students organize and draw meaningful connections between new and old material?

5. Can you give me an example to illustrate what is unique about the way you think and learn as a chemist?

    a) Can you give me an example of how you help your students think like a chemist?
        - Clarification prompts included: The way you look at the world, approach a problem, uncover new knowledge

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6. Are you actively engaged in research at present? Is your teaching affected by the fact that you are actively engaged in research?

    a) If so, can you give me an example of how it is affected?
        - Clarification prompts included: teaching method / techniques / strategies, course grading / format, how material was presented during lectures / labs, etc.
    b) Is your research affected by your teaching? If so can you give me an example of how it is affected?

7. (In general), what is the link between teaching and research?

    a) Do you think that teaching and research activities should be more closely linked?
    b) If so, why and how?

8. What would you miss about teaching if you no longer taught?

    a) Of the aspects of teaching that you would miss, can you give me an example of how one of them contributes to your research efforts?

9. Some say that we currently have an undergraduate culture of receivers of information. Do you agree with that statement? What things can be done to move more toward a culture of inquirers in which undergraduates share in the adventure of scientific discovery?