How Does Faculty Research Activity Affect Undergraduate Instruction in Chemistry? An Exploration of the Perceived Impacts of Inquiry on Pedagogy.

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August 2009

A thesis submitted to McGill University in partial fulfillment of the requirements

for the degree of Master of Arts in Educational Psychology (Learning Sciences Stream)

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Preface

This thesis is built around a manuscript currently accepted for publication pending minor revisions in progress (Hua & Shore, in preparation). This thesis version includes an expanded literature review and text from other materials prepared over the last two years. As first-author in this accepted manuscript, my role included framing the research question, selecting the methodology and theoretical framework, writing the interview protocol, recruiting the participants, conducting the analyses, delineating the discussion and writing the manuscript. My supervisor and co-author, Bruce M. Shore has helped with extensive revisions on style, flow, coherence of the manuscript, as well as the final proofreading. We have also had numerous conversations whereby Professor Shore has scaffolded the research process and helped me synthesize my findings in the broader context of the field.

Acknowledgements

‘Tis far too easy to measure ourselves by the things we cannot do. In my pursuit this Master’s degree, I have learned to build my achievements around the things I can do. The completion of this thesis would not be possible without the following people. With many thanks to Bruce M. Shore, a supervisor who cultivates creativity, confidence, and competence by celebrating differences in the pursuit of common goals; Elaine Randsom-Hodges, for assistance with strategic planning and organization; Haidee for kindred spiritedness; Gina Franco for the remarkable kindness, empathy and encouragement; Sue Hua for boundless love and support; to Son Hong Nguyen for modeling boundless curiosity and scientific reasoning, and last but never least, thank you to Grayden Wagner, my life-partner, for being himself.

Abstract

Academics believe in a symbiotic relationship between research and teaching, although evidence challenges its existence. Previous studies may have defined these constructs too narrowly to detect the perceived relationships. This study used a qualitative approach to investigate chemistry professors' beliefs about the effects of their research activities on teaching practice. Semistructured, in-depth interviews were conducted with 25 chemistry professors from a large research-intensive university. Professors' contended that research affects teaching subject-matter knowledge in the forms of knowledge currency, examples, domain-thinking, and pedagogical knowledge through student interest, as well as pedagogical content knowledge in terms of contextualization and explanation. Findings are contextualized within Shulman's (1987) theory of teacher knowledge as well as current learning theories.

Sommaire

Les professeurs d’université croient que leurs recherches peuvent être bénéfiques à leur enseignement bien que cette croyance n’ait pratiquement pas de preuves empiriques. Nous croyons que les définitions de la recherche et de l’enseignement proposées dans les études antérieures ont été trop simplistes pour établir un tel lien. Basée sur les interviews de 25 professeurs de chimie, notre étude fait la lumière sur leurs croyances au sujet des effets de leurs activités de recherche sur leur enseignement. Les professeurs interviewés relatent plusieurs effets positifs. Leurs recherches leur permettent de conserver leurs connaissances scientifiques à jour, de stimuler l’intérêt des étudiants, de tirer des exemples de la recherche, de donner des meilleures explications et de situer l’information dans un contexte plus large. Ces affirmations ont été classées en utilisant le modèle de Shulman (1987). Nos résultats sont évalués en tenant compte des théories pédagogiques contemporaines et des recommandations du rapport Boyer.

Introduction

The integration of teaching and research has been widely hailed as the ideal center of the scholarship activity of a university, especially that of research-intensive universities. This ideal is incorporated into many university mission statements (Davies & Glaister, 1996) and espoused by senior administrative faculty (Neumann, 1993).

In the literature, the connection between research and teaching, however conceived, is referred to as the "research-teaching nexus." The American Heritage dictionary defines a nexus as "a means of connection, link or tie" or a "core or center." Hence, the research-teaching nexus is most often used to encapsulate the positive, beneficial, and symbiotic ways in which research can support teaching and vice-versa. This nexus has also earned other pseudonyms as a result of the lack of consistent empirical support on its existence: the enduring myth (Hattie & Marsh, 1996, p. 599, as cited in Mclean, 2004), "religious conviction" (Ramsden & Moses, 1992, p. 273, as cited in McLean, 1994) and ideology (Fox, 1992 as cited in McLean, 1994). Regardless of whether or not such a nexus presently exists, there is a nearly unanimous appeal that it should exist. In fact, not only should it exist, it should be developed, nurtured, promoted, supported and strengthened for the benefit of teaching, learning and scholarship (Boyer Commision, 1998; Henkins & Healey, 2005; Prince, Felder & Brent 2007; Zubrick, Reid, & Rossiter, 2001).

When it comes to effectively advancing educational agendas, experience suggests that in order to garner "buy-in" on the vision, the views, and understandings of those who are in the best position to implement and actualize this vision, should be integrated. When it comes to undergraduate learning, the university decision-makers who have the most direct influence on the students, if not most important, are the professors. The literature has presented more speculation and general commentary about, rather than detailed description of, the content and nature of professors' beliefs about the nexus.

To date, the strong and widespread conviction that academics hold regarding the positive benefits of their research on teaching is often mentioned in the literature. For example, McLean and Barker (2004) concluded that "the link is at the heart of the way that some academics construct progression in student learning" (p. 410). In a different study, interviews with academics from seven disciplines and 11 English institutions demonstrated the centrality of the nexus to the identity of many academics: "Academics are the strongest exponents of the argument that research and teaching are central to their work . . ." (Henkel, 2003, as cited in Jenkins 2004). However, the nature, frequency, and strength of, as well as rationale behind, these convictions have more often been the subject of editorial speculation and anecdotal rationalization than of empirical investigation. Do faculty members believe that their current practices naturally, implicitly or sufficiently result in a positive relationship? If so, what kind of relationship do they perceive? How often and to what extent do beliefs in a positive connection occur in specific faculties or disciplines? Such questions are especially relevant because other studies have noted that there is marked, context-dependent variation in how the nexus is experienced (Brew, 2003).

There is currently a drive across North American and Europe to enhance and strengthen a positive, mutually beneficial relationship between teaching and research. The present study is motivated by the assumption that a descriptive, empirically-supported understanding of faculty beliefs informs the content of and approaches to implementing educational change.

This manuscript begins by further elaborating upon the practical and theoretical significance of this area of inquiry. Because there have been several recent summaries of the research-teaching nexus, the literature review that follows builds upon that work and on empirical analyses, as well as the theoretical frameworks that have been proposed for understanding the nexus. The methodology and results section will explain the main theoretical framework upon which our analyses relies (Shulman, 1986). Findings and implications are discussed in light of current learning theories.

Literature Review

Meta-reviews

Feldman conducted one of the earliest literature reviews in 1987. After a review of 42 studies, Feldman concluded, "[T]he likelihood that research productivity actually benefits teaching is extremely small…. [T]he two, for all practical purposes, are essentially unrelated" (p. 275). In a replication of this study, Allen (1996) found a small positive correlation of r=0.10. To address common misunderstandings regarding the importance of such correlations, Allen presented a few hypothetical examples to illustrate the implications of a small correlation. One example used a scenario in which teaching effectiveness was measured on a scale with a mean of 50 and a standard deviation of one. In this situation, a correlation of 0.1 would mean that 55% of researchers and 45% of nonresearchers would have teaching effectiveness scores that fall above the mean. If "teaching excellence" was defined as scores that fall one standard deviation above the mean, one would find that 18% of researchers and 45% of non-researchers are excellent teachers. Allen concluded, "While research is not a perfect indication of high quality teaching, clearly productive research is not inconsistent with quality teaching" (p. 86). In the same year, 1996, Hattie and Marsh published their landmark meta-analysis of 498 correlations from 58 research articles. The average year of publication for these 58 articles was 1980, with 1976 as the median. Whereas Allen included self-report measures in his analyses, Hattie and Marsh (1996) did not. The correlation produced by Hattie and Marsh's study was only 0.05. Therefore, these authors concluded, "the common belief that teaching and research were inextricably intertwined is an enduring myth" (p. 529).

In quantitative studies (Feldman, 1987; Allen, 1996; Hattie & Marsh, 1996), operational definitions for "research" tended to include metrics that are easy to ascertain for individual academics (i.e., weighted and unweighted publication and research activity counts, Likert scale ratings of productivity from peers, number of citations, number of grants, etc.). The measurements used to gauge their teaching effectiveness had greater variation. Although course evaluations were the norm, other indicators included peer evaluation, nomination for or receipt of teaching awards, self-report surveys, instructor surveys on teaching-related constructs (i.e., teaching commitment), as well as more sophisticated measures of student cognitive development. Verburgh, Elen, and Lindblom-Ylanne (2007) noted that although the relationship between teaching and research has been explored within diverse populations and using different levels of analysis (i.e., faculty, administration, and student), the operational definitions used for these two constructs has been oversimplified and limited.

It is interesting to note that the Allen (1996) replication study (which found a positive correlation between teaching and research) is frequently missing from key articles. The following are some notable examples of articles that claimed to include comprehensive reviews yet left out Allen's (1996) article: Jenkins (2000), Marsh and Hattie (2002), Hughes (2004), Griffiths (2004), McLean (2004), Simons and Elen (2007), and Elsen, Visser-Wijnveen, van de Rijst and van Driel (2009). One exception was a review by Prince, Felder, and Brent (2007), which mentioned Allen's positive correlation in passing but concluded that "most analyses come to the conclusion reached by Feldman, Hattie and Marsh, and Jenkins: while research productivity does not preclude quality teaching, the two are unrelated at the individual faculty level" (p. 284).

A review written by Jenkins (2000) concluded that teaching and research are neither inherently connected nor reducible to a simple working relationship. One after another, from individual studies, to comprehensive reviews and meta-analysis, Jenkins asserted that statistical studies have overwhelmingly reached the same conclusion: teaching effectiveness is not connected to research productivity in any simple, quantifiable way. Jenkins added that the major contribution of these meta-analyses is to remind us to be suspicious of general statements, such as "research productivity leads to effective teaching," and "good teachers are good researchers."

What is the practical value of these cautionary reminders? By definition, meta-analyses strive to find aggregate generalizable conclusions that are broadly applicable to the population or phenomenon studied. In another study, Marsh and Hattie (2002) reaffirmed their belief that there was no correlation between the quality of teaching and research. The authors conceded that their meta-analyses had the following "obvious" implications: "Good researchers are neither more nor less likely to be effective teachers than are poor researchers. Good teachers are neither more nor less likely to be productive researchers than are poor teachers" (p. 635).

In summary, Marsh and Hattie (1996, 2002), Feldman (1987), and Jenkins (2000) offered the cautionary reminder that sweeping statements made about research productivity leading to teaching effectiveness should be taken with a grain of salt. However, are academics the ones who make these statements? One cannot help but notice that broadly applicable, widely generalizeable statements, of any sort, tend not to be the kind of statements that academics make. The present study directly asks professors to indicate their beliefs about the effects of research on teaching. Do chemistry professors believe that teaching productivity is equated with research productivity? If they do, what is the extent and nature of this belief? The findings from our study will assess the extent to which findings acquired through a qualitative approach will converge with those derived quantitatively.

Faculty Beliefs and Practices

The majority of the studies with zero-correlation or negative correlation conclusions were published in the eighties. In the 1990s, the bulk of the literature was qualitative in nature, emphasizing that there are no single universal relationship but rather multiple dynamic, context-driven relationships that should be fostered and cultivated for the benefit of students (Brew, 1999). Since Hattie and Marsh's landmark study (1996), a series of articles have identified mediating variables that affect the relationship between teaching and research. Beliefs and conceptions are among the mediators that have demonstrated effects on academics' experience of the nexus. These include conceptions of research (Coate et al., 2001; Prosser, Martin, Trigwell, Ramsden, & Lueckenhausen, 2005; Rowland, 1996), of learning (McLean &Barker, 2004), and of knowledge in their discipline (Martin et al., 2000). The present study does not seek to identify mediators and moderators. As the strand of inquiry, studies that elucidate professors' conceptions of teaching and research help to explain why academics' experience of the nexus varies. Yet exactly what is it that academics believe or experience when they say their research positively affects their teaching? Empirical investigations of the content and nature of these beliefs, especially as they pertain to individual disciplines, remain limited.

Studies concerning beliefs, values, and conceptions that affect the nexus do not shed light on the types of teacher-knowledge that would help integrate research with teaching at the undergraduate level. Indeed, Simons (2007) has suggested that educational research has largely failed to explore the unique teaching potential of researchers. The present study responds to this challenge by identifying the specific ways in which researchers within a single discipline, chemistry, integrate their research into their teaching.

Colbeck (1998) sought to understand departmental and disciplinary differences in the way English and physics faculty members integrated their teaching and research. Using a detailed time-study approach on twelve participants, Colbeck concluded that they integrated teaching and research about one-fifth of the time. This integration took the form of training research assistants, teaching courses related to or informed by their research, and using examples from their own research to illustrate and explain concepts in their upper-year courses. For physicists, the greatest links occurred when students became involved in the faculty member's research activity. In English, lines between teaching and research were blurred; English professors saw the content of the curriculum at the heart of this connection. Colbeck conceded that "it is difficult to bring research into the classroom in 'hard' disciplines such as the physical sciences and engineering for two reasons: hierarchical knowledge structures in those disciplines put most research well over the heads of most undergraduates, and rigidly constrained curricula limit opportunities to bring in new material" (p. ??). Would chemistry professors concur with these suggestions? Does the integration of research and teaching in chemistry also depend on student involvement in inquiry? The present study contributes to our understanding of disciplinary differences in the natural sciences.

Studies that describe the effects of research on specific teaching practices are uncommon. In a case-study comparison of teaching and research from four universities in England and Sweden, Taylor (2008) briefly sketched out a few effects of research on pedagogy. These included being up to date in the subject matter and incorporating staff research interests in upper-year courses. Taylor confirmed findings from previous studies that there are substantial variations among the researchers that derive from their institution, country and department.

One of the more detailed studies that examined specific teaching practices was done by Olsen and Simmons (1996). They examined the extent to which research engagement affected specific aspects of teaching. Informed by Conflict Theory, the study hypothesized that if teaching and research are truly conflicted, faculty who have published more will use approaches to teaching that are considered to be less time-consuming—information transfer approaches to teaching (e.g., faculty would use less active learning and labor-intensive assessment methods in favor of lecturing and multiple choice exams). Their findings included the following: Compared with low-productive research staff, highly productive research staff members were:

- not more likely to use lectures
- not less likely to use discussions
- not less likely to use textbooks over primary resources
- not less likely to interact with students (although they did report knowing their students less well).

Robertson and Bond (2001) noted the lack of studies that have explored the actual nature of the relationship between teaching and research. These authors employed a small-scale, case-study approach to interview nine academics who had written outraged responses in their school newspaper in reaction to Hattie and Marsh's (1996) zero-correlation findings. Their results described the substantial variation in how these academics experienced the nexus. The researchers concluded qualitative and phenomenographic methods should be used more often to examine how professors conceptualize and experience the connection between research and teaching. In a later study, Robertson and Bond (2005) traced the development of teaching and research over time at a single university to place the nexus in a local and historical context. Their case-study approach resulted in the identification of three ways in which the professors brought research into the classroom: by sharing their research findings, by modeling learning through the research process, and by actively engaging students in inquiry.

Theoretical Frameworks

Healey (2005, as cited in Elsen 2009), puts the nexus on a perpendicular continuum for teaching. Emphasis on research content is graphed against research process, and is placed on the horizontal continuum while the vertical continuum places students as participants versus students audience-teacher focus. This model neatly captures part of the intertwined and sometimes confusing conceptualization of what is meant by using the nexus to improve learning.

Griffiths (2004) distinguishes the nexus into the following four types of teaching:

- research-led (involving students in research conferences, publications, poster presentations, social interaction with researchers)
- research-oriented (the teaching of inquiry skills creating a research ethos, helping students understand the processes of knowledge production)
- research-based (inquiry based activities which minimize the division or roles between teacher and student by emphasizing two-way interactions)
- research-informed teaching (the scholarship of teaching and learning, instructor research on the classroom, etc.)

Boyer (1990) called for a re-conceptualization of undergraduate education that involves the integration of four forms of scholarship: discovery, application, integration and teaching.

In a similar light, Brew (2003) framed this ideology as the integration research, teaching, scholarship and learning within a culture and community of inquiry and academic curiosity for the improvement of higher education. Barnett (2000) offered an original view on the nexus by introducing the concept of supercomplexity. Barnett viewed “the academic who comprehends research as the promotion of supercomplexity has also to compound that complexity by promoting radical uncertainty in the minds of his or her students and of enabling them to cope with that uncertainty” (p. 164, as cited in Badley, 2002, p. 454). Unlike other conceptualizations of the nexus that prioritize research over teaching, Barnett deemed teaching as the much more difficult task.

Neumann (1992) proposed a compelling framework to test for and explore the nature of the nexus on the following three levels (p. 162):

- “tangible: the transmission of knowledge and skills”
- “intangible: the transmission of approaches and attitudes to knowledge”
- “global: the direction given to course offerings by departmental research activity.”

In a subsequent study, Neumann (1994) suggested that opportunity for teacher-student interaction be added to the her model because it enabled “students to have closer contact with knowledge and its creation, complexity and excitement” (Neumann, 1994, p. 336). The value in this framework is its ability to neatly categorize the different types of effects of research on teaching, and vice versa. We also seriously considered using this model to interpret the finding of our research. The succinctness and clarity of these categories make them well suited for guiding high-level, institutional and policy decisions on teaching and research. However, on an instructional level, it is more difficult to extrapolate recommendations or applications from findings interpreted within this model because of its generalized nature. That is, as categories, the terms “tangible,” “intangible,” and “global” teacher knowledge and skills are too broad to connect with the current literature on teaching and learning.

Recommended Directions from the Literature

Prince, Felder and Brent (2007) examined the literature to find support for three common recommendations for enhancing the nexus: “(1) bringing research into the classroom; (2) involving students in research projects; and (3) broadening the model for academic scholarship.” Their main contention is that there have been little measurable, empirical demonstrations of the positive benefits of bringing research into the classroom. Healey (2005) and Elsen et al. (2009) advocated for a shift in the understanding of the nexus as a content and product endeavor towards one that emphasizes processes and problems. Grant and Wakelin (2009) have also advocated for a move towards a process view of the nexus. Most studies that have examined the nexus have only looked for the products of such a nexus (e.g., journal articles, course evaluations, publications, joint publications with students, etc).

About this Study

The purpose of this study is not to empirically demonstrate whether there are effects of research on teaching, as this question requires control and comparison groups as well as triangulation from different sources of data. Instead, this study pursues two objectives: (1) To explore the nature of faculty beliefs about the effects of research on teaching, (2) To identify the specific, day-to-day teaching events that professors believe have been informed by their engagement in research. This approach responds to calls in the literature to move toward a more process-oriented view of the nexus.

To date, the interpretation of phenomenological have rarely used a theoretical framework to interpret the findings. The present study starts with specific instructional approaches, experiences and practices that professors self-report as being informed by their research; this study ends by contextualizing these findings in Shulman’s framework for understanding teacher knowledge and skills (1987). Research is operationally defined as scholarly inquiry for the purpose of advancing or creating new knowledge. The analysis brings both the phenomenological and theoretical approaches into one study that adds dimensionality to our understanding of the nexus.

A Rationale for the Methodological Approach and Sample Selection

Brew (2003) and others have said that the relationship between teaching and research is too varied and too affected by context for us to be vaguely combining diverse groups of academics. Disciplinary differences do matter: Knowledge structures, research methods and approaches, and the ways scholars learn at the frontiers in the discipline also vary (Donald, 2002). An advantage of an in-depth study of one discipline is that it ensures, to some extent, that all the responders share knowledge about the ways of knowing in the field, and are all sharing beliefs about the same thing. For this reason, the present study focuses on a single university department--the chemistry department from a research-intensive university. The chosen department has a reputation for interest and excellence in teaching with several members being recipients of teaching awards.

Chemistry as a discipline also faces unique teaching challenges. Learning barriers in chemistry instruction include student misconceptions, the structure of the discipline, the complexity of the content, and the unfamiliarity of students with the tools and language of chemistry (Gabel, 1999). For example, chemistry undergraduates often maintain faulty conceptualizations of the molecular world even after years of instruction (Ozmen, 2004; Teichert & Stacy, 2002). Chemistry is a gatekeeper for a diverse variety of fields that require successful completion of chemistry courses, including nursing, medicine, engineering, environmental sciences and physical sciences. As such, chemistry professors must often contend with a wide variety of competencies and interest-levels within their class.

Importance and Contribution to Knowledge

The imperative for addressing teaching quality in science and the necessity to consider the elements of inquiry currently present in undergraduate science instruction justify the focus of the proposed research agenda and its design. Canada's National Research Council identified three urgent priorities: healthcare, sustainable energy, and the environment (http://www.nrc-cnrc.gc.ca/eng/research/index.html). Chemistry education serves as an essential part of the training for research and applied careers in all of these fields. Meaningful, connected, and integrated learning will occur when students experience science as a human endeavor instead of a litany of material to be regurgitated on exams.

One does not need to look far to find expressions of the importance of integrating teaching and research to enhance student learning. Mission statements and major policy documents across Europe and North America (Boyer, 1999) make strong statements on the beneficial role of research in student learning. The European report (of the STRATA-ETAN expert group on Foresight for the Development of Higher Education/Research Relations) called for a curriculum, which includes more research experiences for undergraduates. The report cites "the list of 'employability' competencies overlaps quite largely with the competencies involved in the exercise of the modern research activity" (Commission of the European Communities, 2002, p. 40, as cited in Stephen & Elen, 2007). In a review of policy documents of institutions within the League of European Research Universities (LERU), Elsen and colleagues (2009) found . . . . The Higher Education Funding Council for England has "shifted from seeing the relationship between research and teaching as necessary, animated and informed, to seeing it as synergistic (not really necessary, but probably desirable), to seeing no discernible relationship whatsoever" (Badley, 2002, p. 43).

The primary contribution of this master's thesis is to illustrate the extent to which chemistry faculty members experience a connection between research and teaching, specifically in the direction of research affecting teaching. This overall connection informs the inquiry-based instructional model proposed by their Faculty and recommended by their discipline (Herron & Nurrenbern, 1999).

Although textbooks can be improved, and top-down institutional curricular initiatives can be proposed, at the end of the day, the reform of science instruction depends on the instructors (Committee on Science and Mathematics Teacher Preparation, 2001). It would be naïve to assume that we can implement curricular reforms when we do not understand what is currently being done, why it is being done, and hence, what should be reformed. It would be shortsighted to address inquiry-based instruction with an all-or-nothing perspective. It is in this light that the present research program is conceptualized and its theoretical and methodological approaches chosen.

This document represents the first of three manuscripts, based on the same data set, being written about the research-teaching nexus. The second manuscript looks at the effects of teaching on research. The third looks more broadly into the instructional outcomes and strategies used by research-active staff in the department of chemistry. This research program will continue through my PhD, at which time I will be analyzing the other side of the equation, the perceived effects of teaching on research, and the reported learning objectives and teaching methods used by these professors. This research has the potential to inform our understanding of barriers to the adoption of inquiry-based instruction by examining beliefs that could promote inquiry or tie instructors to traditional lecture methods. Together, these studies will illustrate the trajectory of growth of beliefs and practices among faculty that leads to increased inquiry-based learning among undergraduates studying chemistry.

Method

Sample

The sample was drawn from the chemistry department at a leading research-intensive university. During the year in which this study was conducted, 28 professors from department had taught undergraduate courses. Of these 28, only three did not participate in our study. Two additional participants, a lecturer from within the chemistry department and a professor from another department were included; these instructors had also taught chemistry courses and expressed interest in the study. In sum, the responses from 25 interviews were analyzed (24 professors and one lecturer).

Procedure

Individual semistructured interviews lasted approximately 60 minutes, on average, (with a range of 24 to 82 minutes). The flexibility afforded by semi-structured interviews allowed researchers to stray from the interview guide by probing topics that emerged during the course of the interview (Warren, 2002). Such probing allowed topics to be illustrated as they are framed and understood by the participant.

The specific interview questions analysed in the present study were worded as,

- Are you actively engaged in research at present?
- Is your teaching affected by the fact that you are actively engaged in research?
- If so, can you give me an example of how it is affected?

If the participant asked for further clarification on the definition of research, the responder stated

- By research, we mean activities you consider to be contributing to your research agenda, activities which you might not be pursuing if you were teaching at a primarily undergraduate university?

The remainder of the interview addressed pedagogical beliefs, as well as intended instructional outcomes and practices related to their undergraduate teaching (a different focus, not addressed here). The complete interview protocol is included in the Appendix A.

Analysis

Descriptive and explanatory questions framed the research study. As a result, the study lends itself to a qualitative design, with considerable reliance on open coding and content analysis. Because the replies were relatively short (two to three sentences on average), we chose to leave the data unsegmented so that the coder would have the flexibility to identify main ideas in the participants' replies. The first step in open coding is to create tentative conceptual categories for coding, by identifying words, ideas, events and actions in the data that can be grouped by similarities. Next, at least two independent raters coded the data to test the framework's ability to adequately represent all the data. In subsequent iterations, these categories were characterized and demarcated, expanded or reduced, and even replaced by different categories as raters revise the framework until a high level of inter-rater reliability is obtained.

Five graduate-student volunteers assisted us in ascertaining the inter-rater reliability; four of these students worked in our research lab and the fifth from another faculty. First, the volunteers were given only the participant responses and asked to identify the main ideas in each response. Next, each volunteer was equipped with a coding kit that included written instructions, preliminary definitions of the six categories, and a worksheet in which the codes were recorded for each response. The volunteers were then asked to categorize the main ideas, which they had previously identified, into one of the researcher's seven categories or into a "misfit" group if the idea was not represented by any of the given categories. In sum, each statement was coded twice, once by the principal investigator and once by one of the volunteers. After the first round of coding slight adjustments were made to help refine and delimit the boundaries of each category in order to minimize overlap. Two of the seven initial categories, with significant overlap, were collapsed into a single category leaving us with six categories. A second round of coding was conducted with the revised definitions for these six categories. The revised categories, seven types of concepts on how research affects their teaching: (a) subject-matter currency, (b) ways of thinking, (c) research examples, (d) contextualization, (e) explanation, (f) student interest, and (g) other (ambiguous). Sources of disagreements were discussed until consensus was reached or until the raters agreed to disagree. The final inter-rater reliability value during this second round of coding was 57% before discussion and 80% after discussion.

The second phase of the analysis involved using content analysis to contextualize these categories under a theoretical framework. Content analysis is a "systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding" (Semler, 2001). With content analysis, a predefined (and often theoretically-driven) framework of categories is used to identify and classify segments of the data. This deductive coding approach is selected when existing theories and frameworks comprehensively represent all facets of the construct of interest. The principal researcher assigned the seven initial categories to three top-level (superordinate) groups which roughly represent Shulman's (1987) perspective on teacher knowledge as elaborated by Borko and Putnam (1996). The final classification scheme was reviewed by a professor who had previously been responsible for teaching first-year graduate-level courses on educational theory. This professor found the reasoning behind the categorization to be sound, which we believe constitutes additional support for the face validity of our framework.

Results

Categorization Framework

The content analysis resulted in the assignment of the six groups of responses representing specific instructional approaches and practices (student interest, currency, contextualization, research examples, explanation, and ways of thinking) to three, theoretically-driven, superordinate categories. These three super-ordinate categories were (a) general pedagogical knowledge and beliefs¸ (b) subject-matter knowledge and beliefs, and (c) pedagogical content knowledge and beliefs. These domains were based on Borko and Putnam's (1996) elaboration of Shulman's (1986) original framework for understanding the types of teacher knowledge and beliefs that are required for effective instruction. Although Shulman's framework was designed to address teaching knowledge, it also applies to organizing teaching beliefs because there is no agreed upon distinction between knowledge and beliefs (Fenstermacher, 1994, as cited in Borko & Putnam, 1996).

Schemes for categorizing teacher knowledge have been proliferating since the eighties (see Borko and Putnam, 1996, for an overview). We believe that it is useful to impose such "schemes" or frameworks when the frame work helps organize, contextualize and simplify the data. Shulman's framework achieves all three of these objectives. Well-established frameworks, such as the one which we have chosen, provide researchers with the terminology to organize, build upon and contextualize findings. Equally important is the substance and contribution of the framework to helping "outsiders," such as administrators, policy-makers or professors in other fields, simplify and understand the findings. To these audiences, we can say that our study investigated the extent to which professors believed their research to benefit different aspects of their teaching; The aspects of interest were the effects of research on teaching knowledge and skills that (a) can be broadly applied to any course (pedagogical knowledge), (b) relate to domain-specific knowledge of the subject (content-knowledge), (c) enable them to make a specific subject more comprehensible to their students (pedagogical-content knowledge).

Eight professors gave responses categorized as general pedagogical knowledge, 15 subject knowledge, and 7 pedagogical content knowledge (total 30); 10 of the 25 professors gave responses that fell under two categories and one gave an extensive reply representing all three. Because our goal was to understand professors' beliefs about the influence of research on teaching, it was not surprising that some professors held multiple beliefs.

Insert Table 1 about here

General Pedagogical Knowledge, Skills (and Beliefs)

This category was not explicitly included in Shulman's (1987) framework, but added by Borko and Putnum (1996) in their elaboration of the framework. According to Borko and Putnam, general pedagogical knowledge and skills are those which transcend any particular domain, and therefore can be seen as contributing to an instructor's "general" teaching abilities, abilities that could be used in any domain.

In our analysis, only one of the six set of responses were notably marked by very general, broad statements on teaching: student interest. *Student interest* highlighted professors' beliefs that their research experiences enables the professors themselves and the topics they present to be more "engaging, "entertaining, "lively, "interesting," or "motivating" to the students. It was almost as if the instructors felt that their research experiences gave them a larger repertoire of stories to tell, stories that would add intrigue to the class because they paint a more vivid picture of the research process and can be told with more personality.

Eight of the 25 professors gave statements that were categorized as *student interest*, making *general pedagogical knowledge and beliefs* the second largest type of effect. In other words, about a third of the professors in our study believed that doing research can make an individual more interesting as a teacher and a subject more interesting to the students. The following are examples of these statements (participant identification numbers are contained within the parenthesis):

- It's obvious why if you do research it helps teaching . . . . You can make it lively. (P29)
- [For the lower level courses] it's more about telling things in class that they'd understand, it's really chemistry [that's] fun, like the magic of chemistry. (P09)
- I think if you are doing research you can use that as a tool to help motivate students. (P11)
- If you want to interest and enthuse them, doing the research is a must. (P20)
- I can take them to my lab and show [them] how it works; to a kid who is 17 years old, it's like a movie. I encourage them to come to my lab and some of them do. You get to see about 25% of the class in there. (P27)
- Students come to class and see that things are being discussed that were published last week. Anything can be discussed at the introductory level. You can always make science interesting and entertaining and nontrivial. (P04)
- I show how it appears from work in a lab to 10 pages typewritten to a one-page communication to two sentences in a textbook. That little snippet meant this much from

four people working in a lab. . . . On a human level, they need to know that. Otherwise it becomes dry, boring, who-cares. (P30)

- [I] try to spark curiosity. . . . On some of [my] asides, I put in research content that comes out of knowing what's going on in the research field. (P31)

Subject-Matter Knowledge and Skills

Shulman used this category to represent a teacher's "knowledge of a subject or a discipline" that is "not unique to teaching" (Borko & Putnam, 1996). Our interpretation includes professors' beliefs about the effects of research on the content that they teach. Three subcategories that were best classified as the effects of research on an instructor's subject-matter knowledge and skills included: *subject-matter currency, research examples*, and *ways of thinking.* Twenty-one professors gave responses that fell into these subcategories—more than any other category. This finding suggests that professors perceive more effects of research on their knowledge and skills within the subject than on any other area of their teacher knowledge. Note that this type of knowledge is independent of any instructional strategies.

Subject-matter currency addressed the effects of research on teaching that are due to professors' up-to-date knowledge of facts, theories, and information. Twelve of the 14 professors whose responses fell under *subject-matter knowledge and beliefs* mentioned effects of *subject-matter currency* on their teaching. This was the largest subcategory of responses in all the data, suggesting that professors in this study believed that the most notable effect of research on teaching is that it keeps them up-to-date for their students. Examples of their statements included:

- The research involves current things. Students come to class and see things being discussed that were published last week. (P04)

- When you’re doing research, you’re involved in activities which the basic knowledge that you teach is needed . . . so you can be topical, you’re up to date. So when students ask about teleportation, I can talk to them about it. (P06)
- Sure, just because when you tend to keep up with research, you attend seminars, you hear things not necessarily related to your own field. . . . There are areas of chemistry that are more applied, where you just have to keep up--new techniques, more sensitive, environmentally-friendly, or whatever. You should be aware of it and they should be taught in the curriculum. (P12)
- You have to [do] research; otherwise you know very little. . . . You learn from books, which is sufficient [only] for low levels. (P20)
- The research keeps you plugged into what’s going on in terms of the worldview on things. After 10 years you start to notice the difference. Some people can stay abreast of things, but it’s definitely being involved, part of [being at the] the leading edge. (P23)
- If I don’t do research, I would be teaching out of a textbook. I would [not know] what’s really going on, it would be five years stale. I wouldn’t adapt to future directions. I would be a high school teacher, not a university professor. (P25)
- How can you teach properly if you’re not aware of what is out there? That is a challenge [for community college] teachers, but if you look at their background, [they] come with a master’s in science. (P26)

Nine professors made comments about *research examples*, making this the second largest overall subcategory. These professors articulated the belief that research affects teaching by enabling them to present examples, current or older, from their own and others’ research and research-related activities, to their classes. The majority of professors spoke of how they used specific examples from their own research (as opposed to the specific focus on currency in the previous subcategory). Although research examples could likewise be used to enliven a course, we believe these statements find a better fit as subject-matter knowledge instead general pedagogical skills because they make reference to the value of domain-specific examples as opposed to general stories and anecdotes about research that could be told in any class. Examples of statements arising from their own research included:

- What you research are the examples you give in your lectures . . . which gives students exposure to your research. (P10)
- I can also give examples of things that I've encountered. . . . One section that I teach is on my research. . . . I can speak from experience. (P19)
- Other people can just follow the example in the textbook, but they don't have an idea of what is the interpretation behind it or the significance. (P17)
- The people who understand what needs to be taught the best are the people who use it. It's one thing to say "Oh, I've had a course on this so I'll repeat it." It doesn't mean you understand it in context, ramifications. . . . [You] can't adapt it for the audience. All you can do is echo what you've done before. (P29)

The third subcategory of responses that we consider to best represented by "subject matter knowledge and beliefs" was *ways of thinking*. We used this subcategory to represent beliefs that engagement in research enables a professor to understand current models of thinking, approaches to problem solving, methods of validating truth and knowledge, etc. Examples of these statements include . . .

- Doing the research is a must, only then do you learn to think critically: You're exposed to the problems, you do them a lot. (P120)

- Without being a chemist you wouldn't look at it critically [or] come up with chemistry approaches to change it. (P125)
- [Research results] demonstrates... how [we] know this is true. (P130)
- You put things more in perspective; [you] see things not as "this is what is,' but [as] "this is what we know." Someone who is not a researcher may take things as "this is so" . . . [they may think] "this is the truth." (P103)
- The fundamental way in which it affects my teaching is that it causes me to do re-preparation of my lectures, to make sure that . . . that they engage current models of thinking. (P118)

Statements in these three categories may or may not have made further reference to specific teaching practices. The key principal that underscores this type of effect is that it refers to "subject matter knowledge and skills" which are familiar to any researcher who are well-versed, whether they be professor, graduate student, or a professional outside of the university community. Hence, it should come as no surprise that the most commonly cited effect of research on teaching was simply increased understanding of the subject-matter.

Pedagogical Content Knowledge

Our third, last, and least frequently cited effect of research on teaching was "pedagogical content knowledge." Shulman used this term to refer to the type of knowledge that he considered most important to teaching . . . specific knowledge of how to "represent and formulate the subject so that it is comprehensible to others." This is the knowledge that determines the "teachability" of the subject. Shulman specified that this knowledge includes "the most powerful analogies, illustrations, examples, explanations, and demonstrations, and an understanding of what makes the learning of a specific topic easy or difficult, as well as the conceptions or preconceptions that students . . . bring with them to the learning of those most frequently taught topics." Two subcategories of interview responses reflect this character of knowledge: Explanation and contextualization.

The description of our *Explanation* subcategory self-evident. These statements represent the belief that engagement in research enables the professor to have better ways of explaining the material. Five professors indicated that research enabled them to better explain their course content. Examples of such statements included:

- I deal with [these] systems myself so I know what techniques you can use to explain this system very well. Other people can just follow the example in the textbook. . . . The department actually tried to teach the course with several other profs before but that didn't work out very well. . . . [Without the expertise, the other profs] don't really make the connection. (P17)
- Every minute of the day, in the back of my mind, I'm thinking to myself, "how does this really work?" . . . By thinking about it so much I come up with ways of explaining it to myself so I give them analogies beyond book[s] that they wouldn't get otherwise. . . . I share with them tricks I have in my mind, . . . what I use to rationalize it to myself. (P25)
- It is a given that if you don't do research, your teaching would be very different. . . . [It's] not [from] books. . . . Here I'm doing it myself, so [it's] easy for me to explain [instead of taking] someone else's example. (P27)

The *contextualization* subcategory represented professor comments on how research affected their teaching by helping them put the topics that they teach into context. This may include statements about their ability to identify the importance, significance, value, relevance, ramifications, applications of their subject matter, or to their ability to contrast, interpret and adapt subject matter. Five professors indicated that their research enabled them to better contextualize the material for their students. Examples from this category include:

- The people who understand what needs to be taught the best are the people who use it. It's one thing to say "oh I've had a course on this so I'll repeat it." It doesn't mean you understand it in context, ramifications . . . [you] can't adapt it for the audience. All you can do is echo what you've done before. (P129)
- [I'm] able to contrast things that are well known from things that are debatable . . . [when discussing certain topics] . . . I can add to it because I'm a part of [it]. (P103)
- When you do research in these areas, you're in a position to assess whether or not it's something useful . . . You can understand the material. If you just teach, then you have a certain level. (P106)
- Other people can just follow the example in the textbook, but they don't have an idea of what is the interpretation behind it or the significance. (P117)

General Discussion

The smallest category of responses was *pedagogical content knowledge and beliefs* (PCK): Seven of the 25 professors (28%) gave such responses. These professors believed that they were able to draw upon their research experiences in order to do what Shulman (1987) referred to as finding "ways of representing and formulating the subject that make it comprehensible to others" (p. 9). The c*ontextualization* subcategory under (PCK) comments indicated one of these ways: Research informed professors' ability to "contrast things that are well known from things that are debatable," "assess whether or not something's useful," interpret its significance, and "adapt it for the audience." The *explanation* subcategory reflected a second way to reformulate the subject for the learner's benefit; the professors' belief that their active engagement with the subject matter through research enables them to better explain the material. Borko and Putnam (1996) concluded their review of the literature with the proposition that both expert and novice teachers may not have enough pedagogical content knowledge to teach for meaningful student understanding of key concepts. Our results are consistent with Borko and Putnam’s assessment: The smallest proportion of professors in our sample believed that active engagement in research enhances their ability to make the subject more comprehensible to students.

An important quality of pedagogical content knowledge is recognition the areas of potential misunderstandings or misconceptions for students (Shulman, 1986). In the year our data were collected, the Faculty of Science adopted a policy that promoted an inquiry-based curriculum based on the Boyer Report. This policy endeavored to connect research and teaching by giving students more opportunities to learn the ways researchers learned. Innovations included a new undergraduate research office, frequent brown-bag lunches, and increased opportunities for undergraduates not already in honors programs (in which a thesis was the norm) to connect to research laboratories. Despite this public initiative, only one of the 25 professors expressed the belief that his or her research engagement helped to better understand students’ potential difficulties or misunderstandings. We shall use this and other indices to track growth of pedagogical content knowledge over several years in relation to both informal and formal experiences in instructional development.

In contrast, 21 of the 25 professors (84%) described the effects of research on teaching in terms of their *subject matter knowledge and beliefs*, the largest category. These professors believed ways of thinking, up-to-date knowledge of the subject and its related fields, and sharing of examples, analogies, and experience from their research, had a positive effect on their teaching. Shulman (1986) emphasized that "a teacher need not only understand that something is so; the teacher must further understand why it is so" (p. 9). These understandings of the rules for validating evidence and knowledge within a discipline are termed *syntactic structures* (Schwab, 1978). Only two professors mentioned the importance of thinking critically in chemistry, and two others directly highlighted how research helps them appreciate differences between "what is" and "what we know," and demonstrate "how [we] know this is true." These statements–categorized as *ways of thinking*–could be tenuously interpreted as referring to syntactic structures. Five comments within the *pedagogical content knowledge and beliefs* category illustrated Schwab's (1978) *substantive structures*—ways in which a discipline organizes its concepts, principles, and facts. In these instances, professors described how research engagement helped put material they taught into context. Substantive and syntactic structures help explain why a topic is worth knowing and how it relates to other topics, both within and beyond the discipline (Shulman, 1986). This category of professors' beliefs may potentially help explain why research activity is not always correlated with teaching effectiveness, and how both could be assessed more usefully in this regard.

The second-largest category was *general pedagogical knowledge and beliefs*. This category had only one subcategory of response: *student interest*. Eight of the 25 chemistry professors—about a third of our sample—believed they were better able to interest and motivate students because of their research engagement and experiences. These results complement Jenkins, Blackman, Lindsay, and Paton-Saltzberg's (1998) observation that to students, professorial research activity lends credibility to the degree and the department in which they are studying and to the diploma or degree that students hope to eventually obtain. Student perspectives obtained through interviews and case studies have indicated that students do experience the course material of researchers as being up-to-date (Neumann, 1994). Together with the findings from the present study, the above-mentioned research contradicts much older research that suggested that undergrads believed “research played ‘little’ or ‘no’ role in their education through their classes” (Bohart & O’Toole, 1980, p. 15). It would be fruitful for future research to examine the direction and nature of trends in student perspectives on the nexus. Furthermore, in highlighting the importance of student interest, beliefs of these researcher-professors echo those of expert teachers who, when compared with experienced but nonexpert teachers, more highly ranked the importance of enhancing student interest and motivation (Henry, 1994).

Two participants raised topics that did not fall into any of the categories or subcategories: “Because you are doing that research, you are also spending less time on teaching” (P11), and “If I mature intellectually, and learn something, it should reflect on students, because they get better quality interactions” (P16). Surprisingly, the former was the only professor who mentioned conflict between time available for research and teaching, given that this topic has been the subject of considerable debate in the literature. However, one hears more frequently that teaching takes time from research. This was the only statement that might be construed as negative. The second point will be incorporated in the discussion following on academic communities of practice. Not one professor stated that there was no impact of research on teaching. This may be partly due to social desirability effects given that the mission of the university asserts that scholarship has a positive effect on teaching: “the advancement of learning through teaching, scholarship and service to society.”

Discussion of Results within Situated Learning Theories

Professors in our study discussed the importance of sharing their research and methods of validating knowledge with students, and modeling ways of thinking that are critical and inquiring. How and to what extent do these activities contribute to student learning? Future endeavors to answer this question may be guided by two conceptual frameworks that fall under situated-learning theories: Cognitive apprenticeship (Collins, Brown, & Holum, 1991) and legitimate peripheral participation (Lave & Wenger, 1991).

Cognitive apprenticeship requires students to be exposed to the thought processes of experts in the context in which such thinking would eventually be utilized, in order for students to meaningfully integrate expert knowledge into their own schemas (Brown, Collins, & Duguid, 1989). Although it is doubtful that a lecture theater provides authentic environments for the practice of chemistry, lectures do form part of students' contextual experiences. Without exposure to experts who are doing research, even in a largely listening role, students would be missing out on elements of learning how to think, approach, and solve problems the way a chemist does. Statements coded in the *explanation* subcategory of pedagogical content knowledge provided clear examples of how thought processes and engagement in research affected the way professors presented the material. Although students recognized some disadvantages of being taught by researchers, they believed, overall, they benefited from being in contact with active researchers and scholars (Jenkins et al., 1998). Further work is required to determine if exposure to thought processes of research scientists, inside and outside class, combined with engaging in student-learning experiences (specifically, inquiry-based problem-finding and solving assignments and laboratory activities), constitute a cognitive apprenticeship in which students meaningfully link new knowledge to their existing schemas.

Another professor said it was important to use personal research experience to respond in an informed manner to student questions that fall outside course content. He discussed this process in terms of giving students the domain's "culture of knowledge." These comments reflect Lave and Wenger's (1991) concept of "legitimate peripheral participation," wherein newcomers in a field are gradually exposed to expert thinking and actions in authentic contexts, allowing them to collaborate, negotiate, and construct meaning increasing participation in a "community of practice."

A community of practice is characterized by "shared competence that distinguishes members from other people" (http://www.ewenger.com/theory/index.htm), an engagement in joint activities in which members of the community interact together and learn from each other, and in which "members of the community are practitioners . . . [who] develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems" (http://www.ewenger.com/theory/index.htm). Professors in our study discussed how their research activities contributed to their ability to maintain a current knowledge base, enabling them to draw from their own research experiences in order to respond to student questions, discuss developments, and describe their approaches to problem solving. According to Wenger (2006), such activities illustrate how communities can develop their practice. In discovering commonalities among their research engagement and teaching activities, the beliefs about teaching and how teaching is influenced by research held by chemistry professors whom we interviewed suggest they have taken the first step and are in the first stage of developing communities of practice. That is the potential stage: Individuals are starting to connect over something they have in common, although they have yet to explore the full extent of that commonality. An exploration and integration of what it means to do research alongside teaching, and to learn in a research-intensive university, are precisely what advocates of inquiry-based learning have been seeking over the past decade (Boyer Commission, 1999).

Conclusions

In a landmark review article, Hattie and Marsh (1996) had concluded that there is no relation between research and teaching but recommended that future studies investigate why the view persists of a symbiotic connection between the two. The present thesis addressed their recommendation by exploring the views of 25 Chemistry Department faculty members in a research-oriented university. All 25 of these instructors articulated the belief that research and research-related activities had a positive impact on their teaching, and were able to provide specific examples.

Methodologically, this study highlighted the importance of allowing participants to define their own experiences. Rather than focusing on the idea of disconnection between professors' beliefs and practice, we see potential in these expressed beliefs. Empirically, as the first comprehensive qualitative exploration of the research-teaching nexus in chemistry, this study adds to the richness of our understanding of this link. Practically speaking, the study informs our educational development efforts to promote and support inquiry-based learning at the undergraduate level.

Consistent with Hattie and Marsh's (1996) later conclusion, Shore, Pinker, and Bates (1990) had found no link between undergraduate pedagogical prescriptions and professors' own methods of learning through their research in the same department two decades earlier. The pedagogical content knowledge category offered a window on the unique qualities that active researchers can bring to their teaching (and ultimately to student learning). Pedagogical content knowledge is fundamental to effective teaching because it enables instructors to anticipate bottlenecks in learning, identify student misconceptions, and formulate and reformulate the content to make it more understandable to learners. If sustained and expanded, beliefs about the positive research-teaching link can serve as a foundation for inquiry-based teaching and the enrichment of undergraduate learning. Barnett (2000) suggested that the key to improving student learning is to promote "teaching approaches that are likely to foster student experiences that mirror the lecturer's experiences as researcher" (p. 163).

It appears possible to start changing the conclusion about no connection between research and teaching. These 25 professors articulated specific examples of research impact on their teaching, however, this change could not yet be claimed to be directly driven by (a) principled arguments such as the Boyer Report, (b) theories such as social constructivism, or (c) emerging practices such as inquiry. In short, we can state that there are research-teaching connections in both the beliefs and recalled experiences of university teachers. Student's experiences remain to be explored.

Implications. The beliefs stated by the chemistry professors in our study are consistent with the first step of creating academic communities of practice—a stage labelled "potential," because there is not necessarily a change in instruction. Pedagogical content knowledge was part of the beliefs of about a quarter of the interviewees. Instructors' beliefs, focusing on fostering student understanding and bringing authentic examples of how chemists think, are a promising beginning. The link between research and teaching has been a belief or assumption in universities for decades. The present study has captured how professors articulate this connection, including examples of how they do so. By generating conversations based on instructors' experiences about this connection, this study could facilitate further developing this link so that progress is made toward the vision of the Boyer report. That vision includes the research-teaching connection in visible practice, not just in beliefs.

Limitations. Limitations of this study include its one-sided exploration of the effects of research on teaching. In an academic community of practice, teaching should also have an effect on research; these potential effects merit exploration to follow. Student validation of the effects identified by the professor would be helpful for triangulating the findings. A marked limitation of this study, and of the majority which have examined staff perspectives, is the near exclusion of faculty who are not research-active. The absence of the viewpoints of students and faculty located in primarily undergraduate institutions make it more difficult to contextualize, validate and judge the importance of the findings.

Suggestions for future directions. What professors and students know and how they come to know will vary. In this study we explored beliefs about how research informs teaching. Such explorations open doors to a more refined understanding of the relation, and of enhanced teaching practice. For example, the types of answers found in this study can inform the creation and use of more specific interview questions to explore instructor beliefs on research-led, research-oriented, research-based, and research-informed teaching. Future research could also be conducted across disciplines, explore students' beliefs, use mixed-method approaches, examine contextual variables that could moderate relations between research and teaching. It would also be valuable to study instructional planning, execution, and outcomes, for example, student learning—not only in the form of marks on tests, but also in ways of knowing, question asking, and evaluating the quality of evidence in support of the growth of knowledge.

"What a scientist does at his desk or in his laboratory . . . [is] of the same order as what anybody else does when he is engaged in like activities – if he is to achieve understanding. The difference is in degree, not in kind" (Bruner, 1963, p. 14). It is in this light that the Boyer Report (1999) was conceptualized. The Boyer Commission (1999) advocated the urgent need for curriculum reforms aimed at giving students more collaborative, inquiry-based, learning opportunities, from the moment they entered university. If the academic communities of practice succeed in moving from the potential toward the active stage, a future study should find professors talking more about learning from their students, sharing ways of knowing, and engaging in joint enterprises with students. According to Brew (2003), such a change would involve the blurring of boundaries between teaching and learning, and the radical reconceptualization of higher education: "In the new model, then, research and teaching are both viewed as activities . . . individuals and groups negotiate meanings, building knowledge within a social context" (Brew, 2003, p. 12).

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Appendices

Table 1

Numbers of Professors who Made One or More Statements in Each Category and Subcategory of Professors' Knowledge and Beliefs about the Effects from Research to Teaching (*N* = 25)

Categories:	General Pedagogical	Subject Matter	Pedagogical Content
	8	21	7
Subcategories:	Student Interest	Currency	Contextualization
	8	12	5
		Research Examples	Explanation
		9	5
		Ways of Thinking	
		5	

Note: The number of responses exceeds the sample size (*N* = 25) because some professors expressed multiple beliefs that were differently categorized

Appendix A: Interview protocol

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 & 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 & 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
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. What things can be done to move more towards a culture of inquirers where undergrads share in the adventure of scientific discovery?

10. Have you heard of "Reinventing Undergraduate Education: A Blueprint for America's Research Universities (The Boyer Report)"?

    a. If yes…

       i. Where did you first hear about "The Boyer Report" ?

       ii. Have you read it? (skimmed it?)

Appendix B: Boyer Report

I. Make Research-Based Learning the Standard

1. Beginning in the freshman year, students should be able to engage in research in as many courses as possible.
2. Beginning with the freshman year, students must learn how to convey the results of their work effectively both orally and in writing.
3. Undergraduates must explore diverse fields to complement and contrast with their major fields; the freshman and sophomore years need to open intellectual avenues that will stimulate original thought and independent effort, and reveal the relationships among sciences, social sciences, and humanities.
4. Inquiry-based courses should allow for joint projects and collaborative efforts.
5. Professional schools need to provide the same inquiry-based opportunities, particularly in the early years.
6. Provision of carefully constructed internships can turn inquiry-based learning into practical experience; internship opportunities need to be widely available.

II. Construct an Inquiry-Based Freshman Year

1. A student embarking upon a degree program at a research university should be adequately prepared to meet the intellectual challenges of that program; if remediation is necessary, it should be completed before entering the program.
2. All first-year students should have a freshman seminar, limited in size, taught by experienced faculty, and requiring extensive writing, as a normal part of their experience.
3. Every freshman experience needs to include opportunities for learning through collaborative efforts, such as joint projects and mutual critiques of oral and written work.

4. The freshman program should be carefully constructed as an integrated, interdisciplinary, inquiry-based experience by designs such as:

    A. Combining a group of students with a combination of faculty and graduate assistants for a semester or a year of study of a single complicated subject or problem.

    B. Block scheduling students into two or three first-semester courses and integrating those courses so that the professors plan together and offer assignments together.

    C. If possible, integrating those courses with the freshman seminar, so that there is a wholeness as well as a freshness to the first year.

    D. Taking advantage of time freed by advanced placement to explore areas not studied in high school in order to encourage students to range as freely as possible before selecting a major.

III. Build on the Freshman Foundation

1. The inquiry-based learning, collaborative efforts, and expectations for writing and speaking that are part of the freshman experience need to be carried throughout the program.
2. Thoughtful and attentive advising and mentoring should integrate major fields with supporting courses so that programs become integrated wholes rather than collections of disparate courses.
3. Mentorships should begin as early as possible and should be maintained, whenever possible, throughout a student's academic career.

4. New transfer students need to be integrated into the research experience with special seminars or similar courses comparable to the freshman seminar.

IV. Remove Barriers to Interdisciplinary Education

1. Lower division courses should introduce students to interdisciplinary study.
2. Academic majors must reflect students' needs rather than departmental interests or convenience.
3. Customizing interdisciplinary majors should be not only possible but readily achievable.

V. Link Communication Skills and Course Work

1. All student grades should reflect both mastery of content and ability to convey content. Both expectations should be made clear to students.
2. The freshman composition course should relate to other classes taken simultaneously and be given serious intellectual content, or it should be abolished in favor of an integrated writing program in all courses. The course should emphasize explanation, analysis, and persuasion, and should develop the skills of brevity and clarity.
3. Writing courses need to emphasize writing "down" to an audience who needs information, to prepare students directly for professional work.
4. Courses throughout the curriculum should reinforce communication skills by routinely asking for written and oral exercises.
5. An emphasis on writing and speaking in graduate courses will prepare teaching assistants for research, teaching, and professional roles.

VI. Use Information Technology Creatively

1. Faculty should be alert to the need to help students discover how to frame meaningful questions thoughtfully rather than merely seeking answers because computers can

provide them. The thought processes to identify problems should be emphasized from the first year, along with the readiness to use technology to fullest advantage.

2. Students should be challenged to evaluate the presentation of materials through technology even as they develop an increasing familiarity with technological possibilities.
3. Faculties should be challenged to continue to create new and innovative teaching processes and materials, and they should be rewarded for significant contributions to the technological enrichment of their courses.
4. Planning for academic units, such as block-scheduled courses for freshmen or required courses for individual majors, should include conscientious preparations for exercises that expand computer skills.
5. Active interchange between units on campus and through professional meetings should encourage and inspire faculty to create new computer capabilities for teaching and to share ideas about effective computer-based learning

VII. Culminate with a Capstone Experience

1. Senior seminars or other capstone courses appropriate to the discipline need to be part of every undergraduate program. Ideally the capstone course should bring together faculty member, graduate students, and senior undergraduates in shared or mutually reinforcing projects.
2. The capstone course should prepare undergraduates for the expectations and standards of graduate work and the professional workplace.
3. The course should be the culmination of the inquiry-based learning of earlier course work, broadening, deepening, and integrating the total experience of the major.

4. The major project may well develop from a previous research experience or internship.
5. Whenever possible, capstone courses need to allow for collaborative efforts among the baccalaureate students.

VIII. Educate Graduate Students as Apprentice Teachers

1. All graduate students should have time to adapt to graduate school before entering classrooms as teachers.
2. Graduate apprentice teachers should be assisted by one or more of the following means: seminars in teaching, thoughtful supervision from the professor assigned to the course, mentoring by experienced teachers, and regular discussions of classroom problems with other new teachers.
3. Graduate students should be made aware of their classroom roles in promoting learning by inquiry. They should not be limited to knowing the old modes of transmission of knowledge without understanding the role of student and faculty as joint investigators.
4. Graduate courses need particular emphasis on writing and speaking to aid teaching assistants in their preparation for teaching as well as research functions.
5. Graduate students should be encouraged to use technology in creative ways, as they will need to do in their own careers.
6. Compensation for all teaching assistants should reflect more adequately the time and effort expected.
7. Graduate students should be encouraged through special rewards for outstanding teaching. Financial awards should be established for outstanding teaching assistants. The permanent faculty should make it clear through these awards and through all they do that good teaching is a primary goal of graduate education

IX. Change Faculty Reward Systems

1. Departmental leaders should be faculty members with a demonstrated commitment to undergraduate teaching and learning as well as to traditionally defined research.
2. The correlation between good undergraduate teaching and good research must be recognized in promotion and tenure decisions.
3. A "culture of teaching" within departments should be cultivated to heighten the prestige of teaching and emphasize the linkages between teaching and research.
4. Prestigious professional research meetings such as national disciplinary conferences and the Gordon Conferences should contain one or more sessions that focus on new ideas and course models for undergraduate education.
5. Sponsors of external research grants can and should promote undergraduate participation, as the National Science Foundation has begun to do, thus facilitating the research experiences of undergraduates.
6. Rewards for teaching excellence, for participation in interdisciplinary programs, and for outstanding mentorship need to be in the form of permanent salary increases rather than one-time awards.
7. Teachers capable of inspiring performance in large classes should be recognized and rewarded appropriately.
8. Committee work at all levels of university life should be greatly reduced to allow more time and effort for productive student-related efforts

X. Cultivate a Sense of Community

1. Research universities need to cultivate a sense of place through appropriate shared rituals that are attractive to the widest possible constituencies within the student population.

2. The enriching experience of association with people of diverse backgrounds, ethnicities, cultures, and beliefs must be a normal part of university life.
3. Residence halls should nurture community spirit.
4. Commuting students must be integrated into university life by making their participation easy and attractive.
5. Collaborative study groups and project teams should be used as a means of creating customized communities for residential and commuting students.
6. Common interests, such as that in maintaining the beauty of the campus setting or supporting charitable or service projects, should be cultivated by creating teams that build community as they work toward a shared goal.
7. Major issues forums, multicultural arts programming, and other extracurricular sharing of ideas, opinions, and arts bring students together, particularly when groups or clubs sponsor or help sponsor the events.
8. Campus programming, such as lectures and performing arts programs, taken as a whole, need to touch the interests of as many audiences as possible.

Appendix C: Misfitting statements

- Because you are doing that research, you are also spending less time on teaching. (P111)
- If I mature intellectually, and learn something, it should reflect on students, because they get better quality interactions. (P116)
- If you are a researcher, you have an inquisitive mind. If you are a good teacher, you can transfer this to your students. (P121-from someone not actively engaged in research)