Editorial

Discipline-Centered Post-Secondary Science Education Research: Understanding University Level Science Learning

Brian P. Coppola[1] and Joseph S. Krajcik[2]

[1]*Department of Chemistry, University of Michigan, Ann Arbor, Michigan*
[2]*College of Education, College of Natural Science, Michigan State University, East Lansing, Michigan*

Received 29 May 2013; Accepted 15 June 2013

We are pleased to present this Special Issue on *Discipline-Centered Post-Secondary Science Education Research*. For the last 20 years, research into learning at the post-secondary level has grown substantially. We are quite fortunate, for this introduction, that the challenge of reviewing the background of this area has already been carried out and made public, less than a year ago, in the National Research Council's report on Discipline-Based Education Research (DBER) (National Research Council, 2012b).

The five goals of DBER (p. 2) provide a starting point for our interest in this topic.

(a) Understand how people learn the concepts, practices, and ways of thinking of science and engineering.
(b) Understand the nature and development of expertise in a discipline.
(c) Help identify and measure appropriate learning objectives and instructional approaches that advance students toward those objectives.
(d) Contribute to the knowledge base in a way that can guide the translation of DBER findings to classroom practice.
(e) Identify approaches to make science and engineering education broad and inclusive.

In their report, the committee charged with defining and describing DBER decided on six areas of undergraduate science education at its foci. From the list, above, the single item (b), "understand the nature and development of expertise in a discipline," carries the burden for differentiating DBER from Education Research (ER), because the other four goals describe Education Research, in science and in general, quite well. We think that understanding the role of the discipline in post-secondary science education is important to address.

A Case for the Discipline

We did not use "DBER" as the title for this Special Issue because we were neither interested in seeing (or worse, causing) a debate about whether teaching, learning and research in the K-12 sector is informed by disciplinary expertise (we think it is), nor were we concerned about drawing

Correspondence to: B.P. Coppola; E-mail: bcoppola@umich.edu
DOI 10.1002/tea.21099
Published online 10 July 2013 in Wiley Online Library (wileyonlinelibrary.com).

sharp lines in the epistemological sand between these instructional levels. To keep the discussion on target, we have acknowledged both "discipline-centered" and "post-secondary science" as the key terms in the title we selected for this Special Issue.

Certainly the disciplines play a role in K-12 science education. A glance at the Framework for K-12 Science Education (National Research Council, 2012a) reveals standards that are strongly informed by the disciplines. And education research can have multiple foci, or emerge from a Psychology-Centered perspective, a Sociology-Centered perspective, and so on. One question that is worth asking, then, is whether the role played by the discipline in post-secondary education has a distinctiveness that can locate a significant difference between education research in postsecondary versus K-12 settings.

In reviewing the literature since the publication of Braxon and Hargens' (1996) analytical frameworks for variation among academic disciplines, Jones (2011) notes the re-emergent growth of a social psychological perspective on disciplines, derived from the Holland Theory of Occupational Classification (Smart, Feldman, & Ethington, 2000). In particular, Smart et al. (p. 19) emphasize how instruction in a discipline is a socialization process: "The term [*socialization*] is not used as a synonym for *development*; rather, it refers to the social pressures on new members to adhere to the prevailing ways of thinking, feeling, and behaving found in the group." One possibility for understanding what might be meant by discipline-centered teaching and learning is the degree to which knowing the facts, concepts, and principles *depends* on their integration with the details of these ways of thinking, feeling, and behaving.

Discipline is a continuum of increasing focus as one moves through education. Although the distinction is fuzzy-edged, one characteristic of post-secondary science education is the shift from introductory survey classes with multiple topics (e.g., High School and General Chemistry) to classes that specialize according to a more specific disciplinary expertise (e.g., Organic Chemistry, Physical Chemistry, Cellular and Molecular Biology, or an Organismal and Population Biology) and the increased chance that the instructor is also a person who is versed in the art of that specific area (an Organic Chemist, a Physical Chemist, a Molecular Biologist, or an Organismal Biologist). The common impression from survey classes, and one that is never a goal, is that scientific knowledge reduces to a bundle of facts. Ideally, disciplinary context provides an integrated understanding, where the "thinking, feeling, and behaving" part of understanding is an indispensible feature of the story. Progressing through the K-20 spectrum, the larger cross-disciplinary ideas about science, as a way of knowing, become highly contextualized through the more detailed study through the lenses of disciplinary focus.

K-12 and postsecondary instructors generally differ greatly in both the time with, and depth of, their prior experiences carrying out work in the discipline. An educational environment designed and implemented by a scientist whose expertise involves years of first-hand generation of data in the discipline carries the possibility, at least, that contextual, practical, epistemological, theoretical, and experimental issues are part of the knowledge and cannot be easily separated from them. As we have said, this is a fuzzy-edged distinction, in that there are certainly K-12 teachers who understand and can convey disciplinary insights from having only limited experiences; and there are postsecondary educators whose Ph.D. does not guarantee that they are aware of, or capable of conveying, the deeper understanding from their fields.

Students at the postsecondary level should begin to experience situations where unilateral one-reason decision-making (Gigerenzer & Gaissmaier, 2011) is not adequate, and where a conditional model of evidence-based decision-making, accounting for variation in individual cases, is required (Falzer & Garman, 2009). This means, for example, that posing a question to a group of university students in an organic chemistry class about a new and unfamiliar situation, such as "which intra-molecular force is more important in this set of molecular conformations?"

ought to be greeted with "give me the experimental result and I can evaluate the relative contribution of the competing forces." The answer to this question, in which a unique balance of multiple criteria must be proposed, for this case, is not a certain and knowable fact that can be conveyed, recalled or selected. In principle, at least, the pedagogical content knowledge of a disciplinary practitioner should provide an increasing degree of fidelity to a broader array of disciplinary values than someone whose experience in the discipline is less extensive or less sophisticated.

If disciplinary expertise and focus is a continuum, then so too must be the influence of the discipline on carrying out education research. Investigators who carry a discipline-centered understanding of the subject, that is, a broad array of integrated disciplinary values, should be able to design experiments that depend more substantially and substantively on that understanding and on those values. They also should be able to observe more detail, interpret with greater subtlety, and find more meaning in discipline-centered data. They should also be able to translate their findings into more highly articulated recommendations for instructional design and/or pedagogical approaches.

On the other hand, if the socialization into differentiated ways of thinking is also what we mean by a discipline, then this might also differentiate approaches to discipline-centered research. We already know that the ground rules for carrying out research in the social sciences and humanities differs from science, and designing astrophysics experiments to test theories of universal origins differ from Phase III clinical trials for an anti-cancer therapy. As discipline-centered education research evolves, disciplinary differences could appear as limitations and restrictions on transferability, that is, the ways in which research is designed and carried out, or in the ways that results from investigating one disciplinary area can inform work in others. For instance, formal ability in statistical reasoning in non-probabilistic fields, such as chemistry and law, stays flat or decreases during graduate education (Nisbett, Fong, Lehman, & Cheng, 1987; Lehman, Lempert, & Nisbett, 1988). Even studies carried out in chemistry and medical education settings would potentially need to take a significant difference in the expectations for statistical reasoning into account.

Relation to the Scholarship of Teaching and Learning

The DBER report (NRC, 2012b) acknowledges that (p. 12) "the boundaries between Scholarship of Teaching and Learning [SoTL] and DBER are blurred." Despite the continued lack of consensus in defining the Scholarship of Teaching and Learning (Hutchings, Huber, & Ciccone, 2011; Ochoa, 2011; Shulman, 2011), the concepts and practices associated with SoTL emerged exclusively from postsecondary education settings, from a sense that mainstream faculty members could learn to investigate and document their classroom practices, and from a sincere motivation to improve and understand what is meant by students attaining a deep understanding of a field. SoTL did not emerge, however, from the realms of educational theory or the learning sciences, and can often come off as naïve and uninformed.

Germane to its foundation in higher education, the conversation around the Scholarship of Teaching and Learning has always been sensitive to the effects of the discipline, and so over 20 years of discourse on SoTL reinforces the premise, above, that disciplinary differences can have a profound effect not only on instructional practices, but also on education research. Unlike DBER, which defines itself as emerging from the sciences, SoTL provides a broader landscape for comparison when considering the role of the discipline, in that SoTL was defined (Boyer, 1990) and refined (Glassick, Huber, & Maeroff, 1997) across the entire academy. Only two of the ten areas selected for an examination of how disciplinary styles have affected the Scholarship of Teaching and Learning were from science (chemistry) and engineering (Huber & Morreale, 2001). The editors, in their analysis of the essays, noted, particularly for these two essays, that there can be tension for disciplinary practitioners when they need to navigate the differences between carrying out research in their native scientific disciplines and carry out social science research when investigating teaching and learning. In their non-probabilistic research domain, chemists, for example, are accustomed to carrying out research with 10^{23} self-equilibrating, cognitively incapable particles, where the Law of Large numbers holds and where control of experimental conditions is real and reproducible over a limitless number of trials. None of these features characterizes the research chemists might carry out in an educational setting, but the expectations from laboratory research can nonetheless linger (see below, "scientific teaching").

Learning-Related Attitudes, Values, and Beliefs

Disciplinary socialization, according to Smart et al. (2000) includes learning "the prevailing ways of thinking, feeling, and behaving," (i.e., dispositions) and these represent aspects of disciplinary understanding that are highly integrated with data, how it arises and how it is used, as well as pedagogical design and implementation, and with education research, in a way that makes them discipline-centered. Once again, there is a continuum, where some dispositions span the breadth of the sciences (relative to the social sciences or humanities) and others are more specifically attached to a given discipline or sub-discipline.

In searching for guidance on how these "prevailing ways" are integrated into formal conceptions of postsecondary education, we are drawn to a recent meta-analysis of 40 years worth of education reform. Slavich and Zimbardo (2012) have proposed a three-level model for what they call transformational teaching. The middle tier of their model, called the Basic Principles (p. 582), includes (a) acquisition and mastery of key course concepts, (b) enhanced strategies and skills for learning and discovery, and (c) positive learning-related attitudes, values, and beliefs. As educational psychologists, the authors included ideas such as motivation and self-efficacy in their third category.

As science educators, we would include discipline-centered "ways of thinking, feeling, and behaving" (i.e., scientific disposition) among these learning-related attitudes, values, and beliefs: those things that accompany learning the more specific subject matter topics and concepts. Developing evidence-based skepticism, for example, probably never appears on the syllabus of a science class, but one nonetheless hopes that improving students' sense of skepticism is an actual learning outcome. Camins (2012) urges that other lessons that scientists have integrated with their conceptual understanding, and should accompany instruction, are: comfort with ambiguity, the search for uncertainty, and learning from failure. In general, the integration of one's subject matter knowledge with the outcomes from a liberal arts education (Ege et al., 1997), and making these an explicit part of learning, is a potentially satisfying way of thinking about the third basic principle in the transformational teaching model.

Challenges

Post-secondary science education research has challenges that distinguish it from work in K-12 settings. University instructors, by and large, are not the product of a deliberate and intentional system of professional development for their classroom duties, so relationships between training and enactment are going to be hard to identify. University students come with whatever background they have gained from their K-12 education, along with prejudices and preconceptions, from the prior instruction they have had in the subject, so accounting for the effects of prior knowledge, beliefs, and experiences is a complex problem. Post-secondary instructors, and their classrooms, have been less open to direct study than their K-12 counterparts, so our sense of how teaching is carried out, in practice, as an observed act, is limited. University students are not a monolithic group, and their learning environments are diverse and multi-faceted. The classroom, *per se*, does not dominate the locus for instruction and learning to the degree that it does in K-12 settings.

An underlying assumption that advocates for science education reform often make, whether the results are from DBER, ER, or SoTL, is best exemplified in the argument made by the proponents for "scientific teaching" (Handelsman et al., 2004; Handelsman, Miller, & Pfund, 2007). They ask: "...why do outstanding scientists who demand rigorous proof for scientific assertions in their research continue to use and, indeed, defend on the basis of the intuition alone, teaching methods that are not the most effective?"

In other words: if scientists, according to this model of "scientific thinking" routinely change their minds in the light of new scientific facts, then why don't they behave the same way about the results from education research when it comes to teaching? Their answers are simple (2004, p. 521): "Many scientists are still unaware of the data and analyses that demonstrate the effectiveness of active learning techniques. Others may distrust the data because they see scientists who have flourished in the current educational system. Still others feel intimidated by the challenge of learning new teaching methods or may fear that identification as teachers will reduce their credibility as researchers."

But perhaps these answers are too simple. Even paradigmatic change in science has never been as easy as "having rigorous proof for scientific assertions" (Kuhn, 2012); or, as Planck put it (1949): "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." Our educational psychology colleagues remind us that changing behavior is complex, requiring the skill (knowledge), the will (motivation), and the thrill (reward) (Paris & Paris, 2001). That is, an overweight, sedentary physician who smokes has all the knowledge needed to make a good choice, and yet changing these behaviors (like teaching) requires more than the facts (Coppola, 1998).

Thinking about incomplete and/or inaccurate understanding ideas that students come to class with, based on their prior experiences, is shifting away from "misconceptions," in which, to a significant degree, the learner receives the blame for misunderstanding, to what some call a "resources" framework (Redish & Sayre, 2013), derived from the "knowledge-in-pieces" framework (diSessa, 1993; Özdemir & Clark, 2007). This latter framework takes into account prior, relevant classroom experiences and their effects on prior knowledge coming into a new class, and how that experience might set strong expectations for how new instruction can activate and possibly reinforce counterproductive ideas. These are highly relevant when thinking about post-secondary students, and could cause the need to re-evaluate work that was based on a misconceptions framework.

In summary, discipline-centered postsecondary science education research is expected to reflect its deeper contextualization of scientific knowledge in both their idiosyncratic disposition (ways of thinking, models, explanations) from the discipline and their deep integration with learning-related attitudes, values, and beliefs about scientific ways of knowing. The role of prior knowledge and experience should play a more prominent role in understanding instructional interventions. Efforts to make direct observations of the diverse contributions to the learning environment of university students is a complex problem, starting with the paucity of empirical information about classroom and non-classroom settings.

The Special Issue

We received 16 submissions from our call for papers, and the peer-review process resulted in the six articles comprising this issue. We have three articles in the area of chemistry, two in physics, and one in the biological sciences. The articles include direct investigations of classroom interventions, international settings, and under-represented student populations. In every case, the authors have attended carefully to balancing the level of disciplinary expertise needed to understand the details of the work with the need to maintain accessibility to a broad audience. We especially thank *JRST* Associate Editor Valerie Otero for her significant contribution in the development of Article #5 prior to our adoption of it for this Special Issue.

Dr. Susan Singer, who chaired the committee that generated the NRC DBER report, has provided the closing essay for the Special Issue. She emphasizes the need for venues, such as this one, for the cross-fertilization of results. The various discipline-based approaches to research on undergraduate teaching and learning, she notes, have created difference emphases and traditions that could benefit from having better ways to speak to one another.

Article 1: Analyzing change in Students' Gene-to-Evolution Models in College-1 Level Introductory Biology

In the first article, Dauer and colleagues look at the effects of using a systems thinking approach in introductory biology. Systems thinking seeks to place conceptual order and organization on what is commonly perceived, by students, as a list of memorized, disconnected facts. Using an explicit representational tool (box and arrow models, which are an adaptation of concept maps), the students learn to connect, literally as well as conceptually, the molecular level ideas of genetics to the population level ideas of evolution.

The study was carried out with 368 students who were enrolled in two of four sections of an introductory Biology course for life sciences majors. Over the duration of the course, the students' models were used as a source of data, and evaluated for complexity and correctness against a backdrop of their prior achievement. Over the first part of the term, the students' models were observed to increase in both factors, and the correctness gap between different student groups decreased. As indicated by their physical models, the students went through stages of accreting ideas, followed by major and minor restructuring of the relationships between them. The authors observed a potentially interesting ceiling effect, where the sophistication of the students' Gene-to-Evolution models flattened out, although the origin of this is open to multiple explanations. This article, and one of the others (#5), speaks directly to grounding instruction in large, introductory classes in principles that allow students to make connections in the otherwise long list of subject matter topics.

Article 2: Self-Regulated Learning Study Strategies and Academic Performance in Undergraduate Organic Chemistry: An Investigation Examining Ethnically Diverse Students

In the article by Lopez and colleagues, an ethnically diverse set of students taking organic chemistry were asked to keep diaries of their study and learning habits. Using a self-regulated learning framework in order to analyze the entries, the content of the diaries was analyzed against a variety of course outcomes: performance on problem sets, construction of concept maps, and on course grades.

The researchers observed, for this population of ca. 90 students, that the students engaged in four common study strategies. There were no differences between the different ethnicities, and the strategies were of the "reviewing" type rather than higher-level strategies, such as using peer-learning options, seeking assistance, and engaging various metacognitive skills.

The study highlights the need for more in-depth monitoring of students' use of resources, not only whether or not they engage with them, but also how they engage with them. In addition, the study raises the question of how background characteristics of students relates (or not) with the resources they select.

Article 3: Students' Conceptual Change in Electricity and Magnetism Using Simulations: A Comparison of Cognitive Perturbation and Cognitive Conflict

Using a population of 45 university-level physics students in Ethiopia, Dega et al. carried out a quasi-experimental design in which subjects were divided by the instructional model used for conceptual change in the areas of electricity and magnetism. With computer-based simulations being used as the trigger, some of the students experienced instruction designed according to a more classical cognitive conflict approach as the control group: "students' existing ideas about the concepts under intervention were made explicit and were then directly challenged." The experimental group was taught with a cognitive perturbation strategy, where the instructor would "move step by step from [students'] preconceptions towards scientific conceptions ... due to the contention that cognitive perturbation would help the students' learning towards the forming of intermediate ... conceptions."

Although both of the groups showed small increases in their normalized gain scores, the effect size was noteworthy. The results from this experiment are interesting, given it was carried out under some sub-optimal conditions (e.g., too many students grouped around too few computers), in that it opens up numerous questions worth investigating in subsequent studies in addition to providing a concrete and well-considered example of how subtle differences in direct instruction can influence outcomes in the context of conceptual change theory.

Article 4: An Investigation of College Chemistry Students' Understanding of Structure–Property Relationships

In Article 4, Cooper and colleagues carry out a qualitative study in order to identify themes in the reasoning used by students for structure–property relationships. Based on semi-structured interviews, 17 students, some from general chemistry and some from organic chemistry, made predictions, and provided explanations about boiling point differences among pairs of organic compounds.

In this study, the researchers identified four areas, or themes, that students included in their reasoning: use of a phase change model, use of representations, use of language and terminology, and use of heuristics. Significantly, although most of the students could rank correctly the pairs of molecules according to their predicted properties, their reasoning was often incoherent, at best, and often ripe with incorrect ideas.

The researchers provide strong and detailed evidence for their conclusion that "simply categorizing 'misconceptions' is not enough," and that students can "do well in ... chemistry courses without a thorough understanding of a core chemistry concept." They support diSessa's conception of knowledge-in-pieces, and argue for instructional programs that more intentionally link new knowledge with prior knowledge, and which ask students to explain more deeply and coherently in the major thematic areas.

Article 5: How Do Students in an Innovative Principle-Based Mechanics Course Understand Energy Concepts?

As with the Gene-to-Evolution article (#1), Ding et al. provide a study of university-level physics instruction in which a small number of fundamental principles is used to provide the backbone for an updated version of the standard, introductory class. In this case, the study involves the development of energy concepts in the Matter & Interactions (M&I) Modern Mechanics course.

Lots of detail is provided for how the M&I course approaches the topic of energy, and this provides a compelling backdrop for why a specific assessment instrument was needed in order to match the intended learning outcomes from this approach, which are significantly different that those from other approaches.

Through a combination of using their assessment instrument with 262 matched pre/post-subject with a small group of interviews, the researchers revealed significant evidence for the success of this principles-based method. Students who stuck with the program, that is, who worked their way to solutions from the basic principles, were indeed more successful that their counterparts who did not. Because energy was the targeted concept, and because the M&I approach is blind to issues of scale, the results from this study potentially have broad and direct application to the way energy concepts are handled in many disciplinary areas.

Article 6: Making Predictions About Chemical Reactivity: Assumptions and Heuristics

In the last article, Talanquer and Maeyer extend the work on studying students' understanding on structure/property relationships to include structure/reactivity relationships. Using interviews with 33 students enrolled in a second-term general chemistry class, the researchers presented their subjects with three chemical reactions and asked the students to arrange them in the order of anticipated extent of reaction. The interview population was judged to be representative of the larger, 1,229 student enrollment through a combination of demographic comparisons with the results from administering the ranking task as a timed, in-class survey to 424 students.

These researchers identified, in their students, numerous assumptions, that is, ideas driven by prior knowledge and experience. These assumptions, which were categorized as intuitive, spurious, and valid, appeared to drive, and constrain, the ability of the students to provide answers to the ranking task. In identifying the various heuristics used by the students, familiar-looking molecules appeared to drive recognition and recall as the main strategy, while one-reason decision-making (if A, then B) was the most commonly employed.

As in a number of the other articles, this article contributes to the idea that designing instructional environments should provide ways to elicit, in addition to providing, the deeper, interconnected, and mutually dependent concepts that comprise scientific explanations. Such teaching practices, which build explicitly on understanding brought into the class, may be more significant for post-secondary students than K-12 students. These practices, which start with the understanding held by students, can provide multiple opportunities to address the coherence and conflict between what students understand coming into a class and the instructional objectives.

Closing Commentary: Advancing Research on Undergraduate Science Learning

In her essay, Singer points to the compelling reasons of national interest that are driving the need to improve teaching and learning at the undergraduate level. Through the DBER report, the National Research Council is seeking to bring focus and attention to the idea that our understanding for the direction of change to make in postsecondary science education is ahead of our widespread implementation of those changes.

Singer acknowledges the same dilemma as we have, above, when it comes to the role of evidence in changing behavior. She states, "evidence is necessary but not sufficient to change undergraduate STEM education." This is a critical point. Another apt scientific analogy might be to not confuse thermodynamics and kinetics. To get from A to B, it does not only matter how much more favorable the thermodynamic destination is, because you always have to overcome the kinetic barrier (in fact, poor destinations with low barriers are often quite attractive pathways to follow). The futurist, Paul Sappho, says it this way (Sappho, 2013): "Never mistake a clear view for a short distance."

Singer's analysis of the contributions from the articles in this Special Issue highlights their placement in areas of research interest: conceptual understanding and conceptual change, use of representations, problem solving, and instructional strategies. She also points to important places where there are gaps in our understanding, particularly in understanding how change can occur in postsecondary instructional settings, the inclusiveness of science education for all students, what discipline-centered expertise means and how it develops during an undergraduate education, as well as the question of what sorts of cross-cutting interdisciplinary understanding might emerge from studying the development of scientific expertise.

The DBER report notes another critical component to change is not waiting until faculty members are hired before acknowledging their broad array of duties, responsibilities and obligations to the discipline, as both researchers and educators. Our system of scholarly development works; it results in scientists who are prepared to identify and take on research problems at the state of the art. This professional, disciplinary education starts in the undergraduate years, which makes this process important to study and to understand. Similarly, broadening the system of professional education for those who are thinking about becoming faculty members, to include DBER and practice for designing instruction, also starting from the undergraduate years, is a strategy that can prospectively take advantage of everything we already know about preparing future faculty and end up "catapulting the next generation past what we could accomplish." (Coppola, 2007, p. 1909).

Summary

As guest editors for this issue and as an associate editor and editor for *JRST*, we sought to have this Special Issue, as we desire to open up the dialog in Discipline-Centered Post-Secondary Science Education Research and provide a resource to share research, methods, and results. Over the last few years we have received numerous research articles focusing on discipline-centered research in higher education, but these manuscripts were scattered among different issues of the *Journal*. Our hope with this Special Issue is to bring a collection of these manuscripts together and to point a focus on how disciplinary knowledge and thinking influence the research in higher education.

Next Steps

Our Special Issue was designed to draw attention to the disciplinary communities of post-secondary science education research, and to provide a place where the question of "discipline" might be raised through the publication of side-by-side articles. This issue, in effect, is the experiment.

Our six articles highlight a number of the ideas that we suggested might make post-secondary science education distinctive from its K-12 counterpart. The significance of prior knowledge in the discipline, among students, played a role in articles #3, #5, and #6, while detailed descriptions of instruction in the subject matter played a role in articles #1 and #5. These latter two demonstrated strongly how principle-based reasoning, as a characteristic of scientific thinking, was illustrated through their instructional designs. Targeting connected understanding, and the need to scaffold and iteratively reinforce the relationships between new and prior knowledge appeared in all six articles.

One common refrain over these past few decades has been: where can research in post-secondary science education be published, particularly the types of extensive, detailed studies that are characteristic of education research, and which covers the STEM fields, in general? As editors, we see clearly the need for the disciplinary research communities represented in this Special Issue to have a place for making their work public, and together.

The work is there. In their review of the literature on chemistry education research (CER), Towns and Kraft (2011) identified 27 relevant articles in *JRST* over the 2000–2010 period (ca. 5% of articles), 49 in the *International Journal of Science Education*, and 28 in the *Journal of Science Education and Technology*, with 255 (67% of those located) split between the *Journal of Chemical Education* and *Chemistry Education Research and Practice and University Chemistry Education*. Roughly the same percentage (7%) of education articles were identified as biology education research (BER) by DeHann (2011), with a 50:50 distribution between studies at the high school level and studies at the university level.

We wrote, earlier, on the potential character of the line between K-12 and post-secondary science education and science education research. We note with interest that one of our long-time *JRST* reviewers reacted to one of our submissions this way: "My problem is that it is too much chemistry detail in nature, and it might interest only a limited number of readers." We think this comment focuses a dilemma: will the details that define discipline-centered work keep post-secondary science education research in the same disciplinary silos that have kept the disciplines separated from one another?

One of the recommendations made in the DBER report (NRC, 2012b, p. 4) is for high-quality journals for postsecondary science education research. By sharing research on teaching and learning across the disciplines, openly and confidently in a well-respected venue, one seeks to inspire, for example, chemists and biologists who face the challenges of teaching large, introductory survey classes to read and understand the details of how Ding and colleagues principle-based mechanics course might inform their own thinking. This is the main rationale used by members of the DBER, SoTL, and Scientific Teaching communities.

We have also offered a line of reasoning that, across the disciplines, science education shares many "ways of thinking, feeling, and behaving" in the "learning-related attitudes, values, and beliefs" included among the instructional goals from transformational teaching. Identification of how (and whether) instruction in organic chemistry or molecular biology results in an increase in scientific skepticism among students is an interesting problem, as is the degree to which it takes place in other science instruction. A venue for critical, accessible, cross-disciplinary discourse is a useful mechanism to facilitate and to study this type of work. And while there are differences, we can learn from each other's work to promote the teaching and learning of science in higher education through research.

We invite comments and reactions to this Special Issue. Its publication also corresponds to a call for papers for a second Special Issue on discipline-centered post-secondary science education research.

Manuscript Submission Deadline: November 30, 2013.

Reviews returned: February 15, 2014.

First revisions due: April 15, 2014.

Second revisions due: May 15, 2014.

Expected publication: August 2014.

Looking to the future: the Association and our publisher, Wiley, are interested in this Special Issue, as well as the one planned for publication in 2014, as trial balloons. If there is enough attention and support generated from these Special Issues, we are potentially interested in spinning off a new journal dedicated to discipline-centered post-secondary science education research.

References

Boyer, E. L. (1990). Scholarship reconsidered: Priorities of the professoriate. Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Braxon, J., & Hargens, L. (1996). Variation among academic disciplines: Analytical frameworks and research. In J. Smart (Ed.) Higher education: Handbook of Research and Theory (Vol. 11; pp. 1–46). New York, NY: Agathon Press.

Camins, A. H. (2012). Three core values of science, engineering and how ed reform contradicts them. In V. Strauss (Ed.). *The Answer Sheet, The Washington Post*, August 8, 2012. www.washingtonpost.com/blogs/answer-sheet.

Coppola, B. P. (1998). The -ills of education reform. Chemical Educator, 3(1), S1430-4171(98)01162-X. http://chemeducator.org/tocs/t8003001.htm. doi: 10.1333/s00897980162a

Coppola, B. P. (2007). The most beautiful theories. Journal of Chemical Education, 84, 1902–1911.

DeHann, R. L. (2011). Education research in the biological sciences: A nine-decade review Paper presented at the Second Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research. Available: http://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_080124#.UbFDgRYwL3I

diSessa, A. A. (1993). Toward an epistemology of physics. Cognition and Instruction, 10, 105–225.

Ege, S. N., Coppola, B. P., & Lawton, R. G. (1997). The University of Michigan undergraduate chemistry curriculum. 1. Philosophy, curriculum, and the nature of change. Journal of Chemical Education, 74, 74–83.

Falzer, P. R., & Garman, M. D. (2009). A conditional model of evidence-based decision making. Journal of Evaluation in Clinical Practice, 15(6), 1142–1151.

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. Annual Review of Psychology, 62, 451–482.

Glassick, C. E., Huber, M. T., & Maeroff, G. I. (1997). Scholarship assessed: Evaluation of the professoriate. Special report of the Carnegie Foundation for the Advancement of Teaching. San Francisco: Jossey-Bass.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., . . . Wood, W. (2004). Scientific teaching. Science, 304, 521–522.

Handelsman, J., Miller, S., & Pfund, C. (2007). Scientific Teaching. New York, NY: W.H. Freeman and Company.

Huber M. T. & Morreale S. (Eds.), (2001). Disciplinary styles in the scholarship of teaching and learning: Exploring common ground. Washington, DC: American Association of Higher Education. and The Carnegie Foundation for the Advancement of Teaching.

Hutchings, P., Huber, M. T., & Ciccone, A. (2011). Getting there: An integrative vision of the scholarship of teaching and learning. International Journal for the Scholarship of Teaching and Learning, 5(1), http://www.georgiasouthern.edu/ijsotl

Jones, W. A. (2011). Variation among academic disciplines: An update on analytical frameworks and research. Journal of the Professoriate, 6(1), 9–27.

Kuhn, T. S. (2012). The structure of scientific revolutions. 50th anniversary (4th ed.). Chicago, IL: University of Chicago Press.

Lehman, D. R., Lempert, R. O., & Nisbett, R. E. (1988). The effects of graduate training on reasoning. American Psychologist, 43(6), 431–442.

National Research Council. (2012a). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2012b). Discipline-based education research: Understanding and improving learning in undergraduate science and engineering. S. R. Singer, N. R. Nielsen, & H. A. Schweingruber (Eds.), Committee on the Status, Contributions, and Future Directions of Discipline-Based

Education Research. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Nisbett, R. E., Fong, G. T., Lehman, D. R., & Cheng, P. W. (1987). Teaching reasoning. Science, 238, 625–631.

Ochoa, A. (2011). The scholarship of teaching and learning: Yesterday, today, & tomorrow. Journal of the Professoriate, 6(1), 100–116.

Özdemir, G., & Clark, D. B. (2007). An overview of conceptual change theories. Eurasia Journal of Mathematics, Science & Technology Education, 3(4), 351–361.

Paris, S. G., & Paris, A. H. (2001). Classroom applications of research on self-regulated learning. Educational Psychologist, 36(2), 89–101.

Planck, M. (1949). Scientific autobiography and other papers (trans. Frank Gaynor) (pp. 33–34.). New York: Philosophical Library. Eine neue wissenschaftliche Wahrheit pflegt sich nicht in der Weise durchzusetzen, daß ihre Gegner überzeugt werden und sich als belehrt erklären, sondern vielmehr dadurch, daß ihre Gegner allmählich aussterben und daß die heranwachsende Generation von vornherein mit der Wahrheit vertraut geworden ist.

Redish, E. F., & Sayre, E., (2013). Resources: A theoretical framework for physics. http://www.physics.umd.edu/perg/tools/ResourcesReferences.pdf

Sappho, P. (2013). http://www.saffo.com/idea1/

Shulman, L. (2011). The scholarship of teaching and learning: A personal account and reflection. International Journal for the Scholarship of Teaching and Learning, 5(1), http://www.georgiasouthern.edu/ijsotl

Slavich, G. M., & Zimbardo, P. G. (2012). Transformational teaching: Theoretical underpinnings, basic principles, and core methods. Educational Psychology Review, 24(4), 569–608.

Smart, J., Feldman, K. A., & Ethington, C. A. (2000). Academic disciplines: Holland's theory and the study of college students and faculty (1st ed.) Nashville TN: Vanderbilt University Press.

Towns, M., & Kraft, A., (2011). Review and synthesis of research in chemical education from 2000 to 2010. Paper presented at the Second Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research. Available: http://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_080124#.UbFDgRYwL3I