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Is the Scholarship of Teaching and Learning New to Chemistry?

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Abstract

From the American Chemical Society to local and national funding agencies, there are substantial resources and outlets for supporting and sharing work on pedagogy and chemistry instruction. Within the discipline, alongside mainstream faculty who are responsible for course and curriculum work, there are those who consider themselves part of a formal “chemical education” community and others who conduct applied science education research (“chemical education research”). While the scholarship of teaching and learning is well situated to engage faculty in general, it arrives into a disciplinary culture with strongly entrenched educational traditions. To what degree will emergent ideas about the scholarship of teaching and learning be integrated within the established educational domains in chemistry? To what degree are the traditions within chemistry education going to shape the discipline’s perspective on the scholarship of teaching and learning? Addressing these complementary questions provides an opportunity to enhance the state of teaching and learning as well as to reshape what it means to be a chemistry faculty member.

Chemistry instruction in higher education is continually, albeit gradually, changing to reflect more progressive pedagogy, an interest in student learning outcomes, and an appreciation for research-based findings. For over 75 years, chemistry instructors (NOTE 1) have regularly exchanged ideas about teaching chemistry at national chemistry and chemical education meetings and in refereed journals, e.g., the *Journal of Chemical Education* and the *Journal of College Science Teaching*. In recent years, some of these faculty members have moved the conversation beyond sharing innovations in teaching methods to reporting more scholarly investigations of student learning and its relation to teaching practice. Unfortunately, there is a tendency to marginalize the responsibility for doing this work rather than to see it as part of a mainstream chemistry faculty member's obligation. For example, the rhetorical use of "chemical educator" is as recognizable and understood as "organic chemist" or "physical chemist," as is the concomitant understanding that chemical educators have pursued the path of "the teacher" rather than "the scholar." A strong, pre-existing culture of chemistry education, then, creates an important backdrop for how the scholarship of teaching and learning will be understood in chemistry.

In general, the scholarship of teaching and learning shows great promise for enriching and supporting chemistry education because it seeks to make systematic, scholarly thinking about teaching and learning a part of every faculty member's life, rather than just those who have claimed its specialization. It relies on examining learning outcomes and on developing and creatively adapting investigative methods for assessing student learning across the chemistry curriculum. It also relies on conversations between the chemistry, chemical education, and science education communities. Chemists must recognize that their disciplinary expertise gives them an important voice in advancing the content, pedagogy, and assessment of chemistry education. The chemical education community (located almost exclusively in chemistry departments) must welcome, encourage, and provide guidance to chemistry instructors who seek to investigate and reflect upon the ways in which their students are learning or struggling with chemistry. The well-established science education research community (located primarily in schools and departments of education) , the wellspring from which chemical education's theories and methodologies flow, must increase the scope of its concern to include higher education. Because schools of education have not historically pursued research in post-secondary teaching and learning, this need is being addressed in part by Ph.D. graduates from Chemical Education programs (those at Purdue University and the University of Northern Colorado are illustrative). The segmentation of science education research is an important part of the canvas on which the scholarship of teaching and learning in chemistry is being painted. Ultimately, collaboration and cooperation between these groups is crucial, and progress will necessitate that members of the three communities make efforts to converse using a common language in order to overcome the barriers presented by increasingly sophisticated specialization.

Challenges facing Chemistry Instruction

Introductory chemistry courses can serve a substantial fraction of any given entering class. At the University of Notre Dame, for example, 55% of the nearly two thousand first-year undergraduates take General Chemistry to fulfill a requirement for their intended major. Heavy attrition within introductory chemistry severely restricts the flow of students pursuing careers across science, health, and engineering fields, because academic performance in this particular course is interpreted by students and advisors alike as a reliable predictor for ultimate success in a scientific or engineering major. Thus, pedagogical interventions are most critically needed in this and other introductory courses so that students with limited high school backgrounds but a desire to succeed can achieve their educational goals. Moreover, keeping the pipeline as open as possible for as long as possible is essential for increasing the representation of women and minorities in technical fields.

Many students have difficulties learning within the conventional structure of an introductory chemistry course. Chemistry is traditionally taught in two distinct settings - the lecture hall and the laboratory. This dual-pronged approach evolved from the archetypical German system in the 1850's as an efficient strategy for training student populations who needed a practical education in a scientific craft (Knight, 1992). Over time, the structure, content, and pedagogical methods of the most populated introductory chemistry courses evolved to serve primarily students who have no intention of majoring in chemistry. One to two years of college chemistry are typically required for majors in engineering, the health-related professions, life sciences, and physical sciences. The sizeable enrollments in introductory courses have led to the common practice of large didactic lectures followed by cookbook laboratories.

Traditional science teaching leaves little room for doing anything but moving predigested information from textbooks to testing. There are few to no safeguards to examine whether actual learning takes place, unless one presumes that correct responses to exam questions necessarily indicate student understanding. Furthermore, laboratory activities are not actually experiments; instead they merely verify observations that have been known and repeated literally hundreds of thousands of times. A pre-laboratory session sets out what is to be observed and how to do it. Post-laboratory sessions review and recapitulate the information. Expository instruction can be done on a large scale with minimal engagement by the instructor. This approach minimizes cost, space, and equipment and is largely impervious to variations between instructors. Unfortunately, it may also be that virtually no meaningful learning takes place in such a disengaging environment (Hofstein, 1982).

The chemistry curriculum is influenced by the accreditation criteria developed by the American Chemical Society (NOTE 2). The vertical nature of the traditional course structure requires that students take courses that emphasize fundamental facts and skills before proceeding to the next level. Publishers compete with very similar textbook products, leaving relatively few practical options for instructors to adopt different selections/arrangements of chemistry topics. The constraints of teaching a content-driven course that serves as a prerequisite for dozens of other courses, combined with the propensity for most instructors to teach in the way they were taught, leads to incremental change in curricular content and instructional method. For example, the absolute change in the University of Michigan's chemistry reform was modest, eliminating General Chemistry for about one-third of entering students and using an Organic Chemistry context for introducing general chemical principles.Yet, it still represents a radical departure for a large undergraduate teaching program (Ege, et al, 1997; Coppola, et al, 1997). New discoveries in chemistry continue to explode, and molecular science has spread to many different fields, yet there is little room to interject these exciting ideas into the time-honored syllabus without displacing a traditional topical area.

Reform movements in chemistry have sought to engage students by promoting active learning and by providing contemporary applications/situations that illustrate abstract concepts (American Chemical Society, 1999). Interactive technologies (e.g., CD-ROM, World Wide Web) remotely deliver simulations, tutorials, animations, and on-line quizzes at a time and pace dictated by the individual student (Wegner, Holloway, & Garton, 1999). Cooperative learning methods bring students together in small groups to develop deeper understanding and problem-solving skills through peer-led discussion (Gosser & Roth, 1998; Coppola & Lawton, 1995), including integrated lecture and laboratory “studio” environments (Apple & Cutler, 1999; Bailey, et al, 2000). In problem-based learning (PBL), the instructor poses an open-ended question about a chemically relevant problem facing society; students work collaboratively to explore issues that they perceive are relevant to the assigned problem. A PBL case study might take a headline from the news (“two would-be chemists die in an explosion while attempting to make methamphetamine”) and turn it into a structured investigation (Bieron & Dinan, 2000). In PBL, there are usually many clear paths that converge on the expected solution (Mills, et al, 2000). Guided inquiry experiences provide a quasi-structured environment for students to explore new material; prompted by the instructor's questions, students develop and test hypotheses through experimental or theoretical approaches. Heuristics have been developed for learners in guided inquiry laboratory settings. One of these is POE (Predict-Observe-Explain; Champagne, et al, 1980), and another is the MORE (Model-Observe-Reflect-Explain; Tien, et al, 1999) method, which was developed for formal laboratory modules.

Although many faculty members have experimented with promising pedagogical innovations in the classroom and/or laboratory, few have treated this work with the same level of sophistication and respect that they have learned to treat their chemical laboratory experiments. Faculty members pursing a scholarship of teaching and learning would assess the degree to which student learning is affected by the selected intervention, to document the process in a way that captures the essential features of the instructional and learning experience, and to provide openings for others to take up the work and advance it. This activity would be as natural to their teaching as keeping a thorough and well-organized laboratory notebook, and it would be as much a part of their formal education as all of the facets of their research training.

Need for the Scholarship of Teaching and Learning in Chemistry

In a speech to the Northeast Section of the American Chemical Society on April 28, 2001, Dr. Robert L. Lichter, Executive Director for the Camille and Henry Dreyfus Foundation, provides a compelling argument for the scholarship of teaching and learning (Lichter, 2001).

> There's a tendency, to which I'll return presently, to divide the chemical universe into two groups: the educators and the doers. Conferences and other gatherings on the topic [of education] tend to be directed to those called the former. I suggest that this is a highly limited perspective and does the profession and the practice, and certainly the students, a disservice. I think the more important questions to discuss are:
>
> What does "chemical education" mean?
> What does "chemical educator" mean?
> Who are the "chemical educators"?
> Why do those expressions even exist?
>
> I suggest that they exist because it's often more convenient to create labels than to address substance. Indeed, the "tyranny of language" so often controls the debate that we can lose sight of the objectives. Jargon dominates as much in the realm of traditional notions of educational change as it does in technical presentations. Here are some examples:
>
> "Active learning"
> "inquiry-based learning"
> "collaborative learning"
> "cooperative learning"
> "content vs. pedagogy"
> "critical thinking"
> "teaching loads" (but not "research loads"?)

> “the scientific method”
>
> Even that widely used expression, the “teacher-scholar.”
>
> Many [of these terms] surface in publications that have any hope of appearing in the *Journal of Chemical Education*. It’s my observation, however, inferred primarily from proposals to us and to other agencies for which I’ve served as a reviewer, and from papers I’ve had time to read, that while these expressions have specific meanings, language nonetheless seems to dominate content and leads to misunderstandings and misperceptions. Would you want to guess how many compositions I’ve seen in which your colleagues say, and I quote, “we’ll *do* active learning,” in that we will create a Web site, introduce multimedia, “interactive” exercises? The mechanics are confused with the processes. Some even call developing those exercises “research”—we’ve turned down a number of such “research” proposals—but more importantly, those activities, no matter how sophisticated, hardly ensure that students are learning, and in an active, engaged manner.
>
> So my first question to you is, what do *you* mean when you say “chemical educator”? What is it that *you* want to accomplish?

The scholarship of teaching and learning puts the focus of the academic enterprise on student learning, and urges the instructor to investigate, document, and present these results. How do students acquire or assemble an understanding of chemistry? How do they identify and replace prior misconceptions with newly learned concepts? Investigations into the ways that students learn when exposed to various pedagogical approaches can only help inform and improve teaching practice when we see the whole picture of instruction and learning, not just “who did what to whom and when.”

Why not leave this work in the hands of the science education researchers or the cognitive psychologists? The answer is simple. Only practitioners of chemistry can recognize the common yet content-rich stumbling blocks that students face when learning chemistry. For instance, chemists have a unique perspective that allows them to ask the quintessential questions about how students visualize, manipulate, and predict the behavior of unseen molecules, precisely because this understanding is uniquely situated in chemistry (Brown, et al, 1989; Lave

& Wenger, 1991; Vanderbilt, 1990). Although one can certainly benefit from reading the work of others, it is important that an individual instructor explores and reflects on the learning approaches adopted by his/her own students. This point underscores an important distinction between traditional chemical education research and the scholarship of teaching and learning. Education research is familiar; investigators not responsible for the instruction in question tend to gather data from student performance of one kind or another, such as exams, surveys, and interviews, and proceed to analyze those data from some theoretical perspective. The scholarship of teaching and learning is centered on faculty investigating the learning of their own students in the context of courses or curricula in which they are personally involved, and in exploring the ways in which that work can be made more transparent and open to assessment.

The chemical education community has tried to establish general patterns of learning behavior and to promote “best practices” in chemical instruction. Unfortunately, these can end up sounding rather like heroic accounts of what was done to students rather than expositions of student learning and its alignment with instructional practice. Rarely, if ever, does the account include how the education of future practitioners should be informed by the results. More basic, however, is that undergraduate education is ultimately impacted at the ‘grass roots’ level in departments, classrooms, and laboratories where faculty and students learn and interact. We carry out pedagogical experiments in all instructional contexts, and the impact on a target population should be recorded, assessed, and reported - at the institution where they are being introduced, in the instructional setting, under whatever particular conditions exist. Chemists understand this well enough to always plan and carry out laboratory investigations with care, letting nature tell us what the results, from setting certain boundary conditions, are. If this kind of scholarly investigation takes place within chemistry classrooms, carried out and concluded in ways that display the benefits of the work for others, then the practice of chemistry education can advance.

The scholarship of teaching and learning invites faculty at all stages of their careers to ask questions about how students actually learn in their laboratory or classroom environments. This way of thinking about teaching and learning has the potential to reinvigorate established faculty, who have become complacent, discouraged, or simply bored about their work. It can assist younger or aspiring faculty in developing effective teaching styles that promote lifelong learning habits in students. This scholarly endeavor can nucleate communities of chemists who share a passion for inquiry and for teaching. The need for mentoring relationships among investigators mutually engaged in the scholarship of teaching and learning is no less essential than the mentoring relationships developed and fostered within discovery-based chemical research. The professional development infrastructure is already in place to support students and research advisors in laboratory-based discovery. Undergraduate students are identified early on for that identifiable yet un-quantifiable "spark for research" as they do their work under the watchful and experienced eyes of a chemist. Aspects of the undergraduate laboratory courses will cull out the promise of the potential future chemist. In chemistry research laboratories, teams comprised of faculty members, post-doctoral, graduate and undergraduate students all work together, each at their own strengths, on a research problem. By broadening this infrastructure, from undergraduate course design to taking on course and curriculum development as a "teaching problem," the true scholarship of teaching and learning will become not so much a thing "to do" as much as the way things are done. The fruits of this effort will be two-fold. First, students will receive a better chemistry education because instructional practice will take place in a significantly more informed way than it does today. Second, the faculty of tomorrow will see that the same intellectual processes can benefit both teaching and research.

Investigating Teaching and Learning in Chemistry

In many ways, a scholarship of teaching and learning in chemistry is similar to the scholarship of discovery in chemistry. One begins with a question or hypothesis that defines the goals and objectives of what is to be better understood. An investigative study is designed to collect evidence that reflects on the validity of the hypothesis, which in turn reveals underlying ideas, creates new questions, requires modification of the original proposition, and so on. The results of the investigation are analyzed using methods that are widely accepted by the community, and the work is subject to full disclosure, commentary, and the test of generalized applicability. Scientists typically document an observable phenomenon before exploring its mechanism or cause. Similarly, chemists often prefer to measure summative learning outcomes before delving into studies on the formative learning process. While the existing chemical education and chemical and science education research communities provide important intellectual, historical and methodological milestones for the scholarship of teaching and learning, there is concern that their work, which has often been marginalized, will be ignored and reinvented under this new scholarship rubric. This results from a fundamental misunderstanding that confuses the scholarship of teaching and learning with the scholarship of discovery about teaching and learning. Science education research, carried out by faculty in schools of education or those in chemistry departments, is crucial in opening new areas of inquiry and establishing the theoretical backbone on which all scholarship can grow. The scholarship of teaching and learning provides the heretofore unavailable pathway for chemistry professors, who are all chemical educators, to systematically investigate and report on their classroom work in an informed way.

The scholarship of discovery and the scholarship of teaching and learning differ significantly, of course, in the types of evidence that can be gathered and in the basic characteristics of the subjects being investigated. Discovery-based research in chemistry involves performing reproducible experiments on a well-defined system. In most cases, chemical investigations are carried out on samples with an extremely large number(10^{23}) of atoms and molecules that respond at extraordinarily fast rates after the system is perturbed. In some respects, this makes getting results with high levels of confidence much easier in chemistry than nearly anything else; it also means you know when something has gone wrong. Measurements are repeated while systematically varying experimental parameters to learn the dependence of observed outcomes on initial conditions. Chemists are probably more comfortable with causation than other disciplines because correlation gets an enormous statistical boost due to large population sizes in chemical samples and to boundary conditions that can be precisely regulated.

The advantages to doing chemical research can make chemists skeptical about collecting information that is more like social science. The evidence that chemists find compelling is usually quantitative rather than qualitative, and experiments that cannot be reproduced are typically not trusted. A chemist might argue that “teaching is teaching” and not subject to discovery and advancement; after all, you come back the next year, and although the subject matter is the same, it is a new group of students. Student learning is intrinsically non-reproducible, and relies on assessment methods not found in the chemistry laboratory. Focus groups, surveys, and scoring rubrics are as unfamiliar to chemists as titrations, distillations, and spectrograms are to sociologists.

Chemical education research and the scholarship of teaching and learning both suffer from the same methodological prejudices. Ironically, the development of scholarly practices in chemical research 200 years ago encountered the same growing pains that the scholarship of teaching and learning experiences today. Theoretical chemistry in the early nineteenth century, like its ancient Greek philosophical progenitor, did not sully itself with experiment and inquiry, but rested on pure inductive reasoning. The power of inquiry, full and open disclosure, reproducibility and critical review advanced the practice of chemistry from its neo-mystical alchemical roots. But it did not come easily, nor was it universally embraced. Justis Leibig, in 1834, on the eve of giving up theoretical chemistry, wrote to Berzelius that “the loveliest theories are overthrown by these damned experiments; it's no fun at all being a chemist any more.” (Berzelius, 1982; NOTE 3) Professors routinely teach with their own beautiful theories about teaching and learning that may or may not be aligned with their instructional goals or even their own underlying philosophies about teaching and student learning (NOTE 4). With our willingness to accept anecdotal pedagogical ‘magic bullets’ (new technologies, group learning, etc.) evaluated on their modes of implementation rather than demonstrated efficacy (deeper understanding), the scholarship of teaching and learning in chemistry resembles greatly the situation 200 years ago in the historical development of scholarly research practices. There is an equally important burden of proof on the scholarship of teaching and learning to lead the field of discipline-centered teaching and learning of out of its alchemical age.

Examples of Inquiry into Teaching and Learning in Chemistry

As described earlier, the distinction between science education research in chemistry ("chemical education research") and the scholarship of teaching and learning in chemistry is one of those tensions that a number of disciplines are wrestling with (Hutchings & Shulman, 1999). Understanding the complementary relationships between these forms of work, rather than worrying about competition, is a way to defuse this anxiety. A nice example of science education research in chemistry is represented by the studies on what investigators called conceptual problem-solving versus algorithmic thinking (Nurrenburn & Pickering, 1987; Sawry, 1990; Pickering, 1990; Nakhleh & Mitchell, 1993; Beall & Prescott, 1994). These are prototypical science education research studies. Using student examinations, the researchers demonstrate that students who can solve numerical (algorithmic) chemistry problems that relate to a given concept cannot select the correct answer to a question that ostensibly relates to the same concept but is represented by pictorial images of atomic and molecular particles in different arrangements (conceptual). On the one hand, the experiment demonstrates convincingly three important ideas, namely, that students can solve mathematical word problems successfully without tapping into the underlying concepts, that the representational form used to transmit ideas matters because learners springboard off of surface features, and that representational interconversion is not trivial (Kozma, 2000; Kozma, et al, 2000; Kozma & Russell, 1997). On the other hand, the studies are rather decontextualized and sterile. Little to no information about the nature of the instruction leading to questioning using these different representational forms is given; no reflective commentary on how these outcomes fed back to change the instructional delivery; no follow-up data collection with students about why they answered these problems so differently; no sense of deeper understanding about student learning is presented; no follow-up on how modified teaching practices have changed (or not) student performance and student learning. Yet, based on these results, most texts now incorporate a greater number and variety of pictorial images, and the American Chemical Society now offers a "concept-oriented" version of its standardized general chemistry examination with problems formatted in pictorial forms. One critic has rightly pointed out that, in the absence of additional information, there is no way to distinguish student performance on these pictorial problems from just another version of algorithmic thinking because no data has been collected demonstrating that performance on these questions is tapping into any deeper conceptual understanding than the numerical problems (Beall & Prescott, 1994).

A second example also relies heavily on science education research in carrying out its assessment program, but moves closer to documenting the classroom context. Wright and his coworkers (Wright et al, 1998) integrated group learning methods into an analytical chemistry course. They describe the classroom teaching situation in the course where the intervention is used, as well as the "control" classroom, where an excellent teacher using traditional didactic methods taught a different section of the same course. These investigators engaged faculty from outside the chemistry department to orally interview, blindly and randomly, students from each of the sections. The proposition made by the Wright team was that the students who were accustomed to having conversations about chemistry concepts would demonstrate greater confidence and better subject matter mastery than those who were not involved with the group work. Instructional goals, methods, and assessment were clearly aligned for the experimental group. Although Wright's critics argue that chemists should have carried out the interviews so that subject matter mastery could be judged more deeply, the affective skills of the students in Wright's section were clearly superior to those in the other section.

Both authors of this essay have themselves engaged in classroom-based research. When Coppola and his colleagues at Michigan redesigned its introductory laboratories in an attempt to teach more contemporary approaches to laboratory problem-solving, they used graduate student and faculty responses to the assessment task as the baseline against which to measure student performance after coding interviews on solving an unfamiliar laboratory task (Coppola, et al, 1997). Again, the objectives, implementation and assessment of the instructional intervention were aligned, the classroom context was significant to the investigation, and the implications of these results on student learning in this course were examined.

For the past few years, chemistry graduate students and faculty members at the University of Michigan have joined together to form "instructional R&D" groups to work on teaching problems in a way that draws from their experience in pursuing research problems. The students, who are members of Coppola's future faculty development program as well as mainstream chemistry Ph.D. candidates, need to work with faculty colleagues on an instructional design project as part of extra program work in which they elect to participate. They also implement and assess their project in the department's teaching program. For instance, three students integrated an active learning component to classroom chemistry demonstration work into a 250-student section of first-term chemistry. Six months after the course ended, they interviewed students from their section of the course as well as “A” students from sections where the same demonstrations had been done as a more traditional, passive display. Students in the experimental section were not only better able to describe the details of the experiment, they were far and away superior at relating the underlying chemistry meaning, understanding the precise reason for why the demonstration had been done in the first place.

Jacobs, a mainstream chemistry research faculty member at Notre Dame, reports how a seminal event involving a despondent student motivated him to investigate his own teaching(Jacobs, 2000). This not only led him to integrate group methods into a course with a high fraction of at-risk students, but to gather multiple sources of complementary data related to student performance in order to understand the nature of his intervention. Besides the improvement in student performance in the course, Jacobs also tracked these students into their subsequent chemistry courses and demonstrated that there had been a profound effect on them. Finally, the course design has survived Jacobs’ departure from the course, and comparable results have been observed when another instructor has implemented the method.

Supporting the Scholarship of Teaching and Learning in Chemistry

Support for work in chemistry education, and science education in general, is quite strong. The American Chemistry Society (ACS) is the world’s largest and possibly best organized professional scientific society, and it provides energy and identity for thousands of faculty who are concerned with chemistry education. All of the contexts that exist inside and outside of the ACS can be fertile ground for supporting and disseminating work about the scholarship of teaching and learning in chemistry.

The Division of Chemical Education is over 75 years old, and it plays a strong, visible and permanent role in the semi-annual national ACS meetings as well as at every regional meeting. The Division has sponsored 16 Biennial Conferences on Chemical Education, the last of which, in 2000, drew over 1700 participants. The ACS web site (www.acs.org) contains detailed information about programming and the other resources mentioned here. The Division also has published the *Journal of Chemical Education* since 1923, which is widely recognized as an important forum for chemistry education. The ACS works through divisional and society-wide committees. The Division of Chemical Education sponsors the Committee on Professional Training as a certification vehicle for undergraduate curricula. Recent discussions have also raised the possibility of extending this work to graduate programs. The ACS Committee on Education takes up everything from input on important policy issues which impact education to the production and publication of teaching materials. The ACS has also just created an office of graduate activities, including its formal association with the national Preparing Future Faculty program. Finally, the Division of Education hosts a Committee on Chemical Education Research that meets regularly. One of the first acts undertaken by the Committee was to endorse the broadened definition of scholarship advocated by Boyer in *Scholarship Reconsidered* (Boyer, 1990).

There are a number of other venues where work on the scholarship of teaching and learning in chemistry can be presented. Publication outlets include *The Chemical Educator*, the *Journal of College Science Teaching*, the *Journal for Research on Science Teaching*. Interdisciplinary journals such as *Science & Education*, and *HYLE: International Journal for*

Philosophy of Chemistry, also represent places where publications on the scholarship of teaching and learning can appear. In 2000, the Publications Division of the ACS considered a proposal to create a dedicated journal for research in chemical education. In addition to the various ACS meetings, there is a biennial “ChemEd” meeting that focuses primarily on precollege issues, and an International Conference on Chemistry Education that is also held biennially. The National Association for Research in Science Teaching hosts an annual meeting where the representation from higher education has grown from a handful of participants in the early 1990s to a full set of sessions in its own dedicated strand. After the first Gordon Research Conference on Science Education proved to be too diffuse in its scope, it was replaced by an ongoing meeting that focuses solely on college chemistry instruction.

There are a number of funding sources that can support work in the scholarship of teaching and learning in chemistry. Locally, departments and institutions often have internal sources of funding that can be used to carry out projects, and perhaps seed higher levels of external support. The Research Corporation is the oldest foundation providing grants that can be used to advance teaching and learning, and its Cotrell Scholars program recognizes the work of young, mainstream faculty who also make significant contributions to education. The Camille and Henry Dreyfus Foundation is dedicated solely to support work in the chemical sciences. Dominating both of these smaller organizations, of course, is the National Science Foundation, which hosts a rich array of programs devoted to education in both its disciplinary Divisions (such as chemistry) and through its Education and Human Resources Division.

Local, regional, and national recognition for individuals who show leadership in their contributions to chemistry education are another important way that work in teaching and learning can be placed on a par with discovery research. The Chemical Manufacturer’s

Association sponsors a series of Catalyst Awards every year, and the American Chemical Society sponsors the Pimmentel and James Flack Norris awards.

While none of the support mechanisms mentioned here (journals, meetings, external funding, and awards) is dedicated to recognizing the scholarship of teaching and learning explicitly, they represent the usual array of resources that support scholarship, in general, and will therefore naturally be adapted to work in any emergent area.

Conclusion

The title of this essay asks "Is the scholarship of teaching and learning new to chemistry?" The answer is "yes and no." As a discipline, chemistry has a long and honored tradition of recognizing and supporting work related to teaching and learning. Prior and ongoing work in chemistry education and chemical education research has an important synergistic relationship with the scholarship of teaching and learning in chemistry. If those who care about and contribute to chemistry education choose to collaborate rather than compete, chemistry instruction and its investigation can advance through a large community whose informed practices complement and build off of each other. The scholarship of teaching and learning, as a philosophical construct centered on investigating classroom work, can pull the pieces of chemistry education together for the mutual benefit of individual present and future faculty members, their students, and also for the profession of the chemistry professoriate as a whole (Coppola, 2001).

NOTES

1. We recognize that there is a significant amount of chemistry instruction provided by individuals who are not considered to be faculty because of their rank or employment

situation, including the teaching done by graduate and undergraduate students in lecture, recitation, and laboratory settings. For convenience, we will use terms such as “instructor” and “faculty member” and “teacher” interchangeably.

2. The American Chemical Society’s Committee on Professional Training (CPT) reviews self-reported documentation provided by chemistry departments every five years. Unlike the role that accreditation plays in engineering, certification of a chemistry degree by the CPT does not influence employers or graduate schools. In fact, CPT embraces a fairly wide array of curricular programs and invites departments to share their models for how individual programs have met the broad CPT guidelines. Anecdotally, the guidelines are invoked by small, service departments with few majors who seek to retain faculty lines, arguing that the loss of CPT certification will result if the only faculty member who teaches advanced inorganic chemistry is not replaced.
3. Die schönsten Theorin werden durch die verdammten Versuche über den Haufen geworfen, es ist gar keine Freude mehr Chemiker zu sein.
4. “Anyone who enters a classroom or other teaching situation has a philosophical framework (a teaching philosophy) that guides their practice, so it is ironic that writing down a statement of teaching philosophy outside of a job search is a relatively new practice in higher education. Significant publications on this topic did not appear until the 1990s (Goodyear and Allchin, 1998; Chism, 1997-98).” (Coppola, forthcoming)

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