CASTL Technical Report No. 1-06

Paths of Inquiry: An Exploration of the Effects of Systematic and Intentional Inquiry on Student Learning in General Chemistry Lecture, Recitation, and Labs

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The Center for Advancing the Study of Teaching and Learning (CASTL) was established in 1998 in the Department of Foundations and Leadership at Duquesne University School of Education. CASTL engages in research programs dedicated to understanding, advancing and disseminating evidence-based study of the teaching-learning process.

**Mission and Goals**

The Center for Advancing the Study of Teaching and Learning promotes systematic and intentional inquiry into the teaching-learning process and, through careful and collegial study of learning-centered environments, seeks to advance the understanding and dissemination of evidence-based study of the teaching-learning process in service of all learners.

To promote its mission, CASTL intentionally pursues the following goals:

- Promote socially just, learning-centered environments that bring excellence and equity to all learners;
- Foster systematic and intentional inquiry into the beliefs that educators hold about educational theory and research and effective practice;
- Honor research, theory, and practice as legitimate and complementary sources of knowledge regarding the teaching-learning process;
- Elevate professional learning and educational practice to the level of scholarship;
- Advance the conceptual framework of leadership as learning;
- Develop a knowledge network fueled by researchers, theorists and practitioners who contribute to advancing the study of the teaching-learning process;
- Establish and perpetuate an international community of teacher-scholars representing a variety of teaching and learning environments;
- Promote and coordinate communication within a network of educational institutions and organizations that collaborate in the recruitment and education of teacher-scholars;
- Create a culture of professional learning based on research situated in schools and in other learning environments;
- Examine and develop methodologies by which the teaching-learning process is studied;
- Advocate for the enhancement of the teaching-learning process in service of all learners; and
- Share what is learned about the teaching-learning process.
This report is one of a series from our ongoing research effort to advance the study of teaching and learning. If you have any questions or comments on this report, or if you would like to find out more about the activities of CASTL, contact:

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Our project, “Paths of Inquiry”, is a collaboration between the Department of Chemistry (DoC) and the Center for Advancing the Study of Teaching and Learning (CASTL) at Duquesne University. The proposed project builds on a previous collaboration between two of the researchers—Moss and Madura—who established a research team comprising chemical educators (from DoC) and educational psychologist (from CASTL) for the project.

Although the project is only a Phase I exploration, it will address several components of the Cyclic Model for Knowledge Production and Improvement of Practice in Undergraduate STEM Education (NSF, 2006; Rand, 1999). The primary foci of the project, however, will be on two components: “Creating Learning Materials and Teaching Strategies” and on “Developing Faculty Expertise”. The materials and strategies that emerge from the project will serve undergraduate students, graduate teaching assistants, and faculty. The process by which the materials and strategies will be generated and then used by instructors is a form of systematic and intentional inquiry designed to improve teaching effectiveness.

And has been noted in any number of reports, teacher learning is critical to student learning (AAAS, 2004; Bain, 2004; Darling-Hammond, 1998; Huber & Hutchings, 2005; National Academies of Science, 2003; National Commission on Teaching and America’s Future, 1996; National Science Foundation, 2002, 2003; Shulman, 2004; Woodrow Wilson Foundation, 2005). “Paths of Inquiry” will engage graduate teaching assistants (TAs) in significant learning: learning focused through a process of systematic inquiry and undertaken with the intention of overcoming on what they perceive to be the difficulties or obstacles that stand in the way of undergraduate student learning in general chemistry. Undergraduate students will benefit from what TAs learn. As every faculty member knows, teaching others results in teacher learning. The faculty who mentor TAs will benefit also from what TAs learn (c.f., Lopez-Real & Kwan, 2005).

**Purpose**

The primary purpose of the proposed project is to engage six TAs in systematic and intentional inquiry in an effort to improve student learning in the recitation and laboratory sections of the general chemistry course at Duquesne University.

**Goal**

In the course of the project, our research team—comprising chemical educators and educational researchers—expects to achieve the following goal:

To understand the perceived needs of instructors with regard to enhancing undergraduate learning in general chemistry at Duquesne University and to develop and test resources (using a process of systematic and intentional inquiry) that will support instructors in understanding respond to the perceived needs that will support instructors in their efforts to both understand and to enhance student learning.

**Objectives**

In order to achieve our Phase 1 goal, the research team will pursue three objectives, one for each year of the project:
Objective for Year 1. Identify and document obstacles to student learning in the recitation and lab sections of general chemistry.

Objective for Year 2. Develop resources (and a process for using those resources systematically and intentionally) that place key principles of learning theory in the context of learning general chemistry at Duquesne University.

Objective for Year 3. Test the effectiveness and efficacy of the resources (and attendant process) for enhancing the teaching effectiveness of TAs and, in turn, the learning of students.

The remainder of the project description includes a rationale, the context, the work plan, and the expected impacts of the project. Each aspect is described in turn.

Rationale for the Project

Using relevant literature to justify our claims, we address the significance of our project by identifying the need for the project, its relationship our research team’s log-term goals, and its relationship to chemical education.

The Need for the Project

“Almost every aspect of science—except pedagogy—has undergone a substantial change in the last 2000 years.” (Spencer, 2006, p.528). Mindful of this issue, researchers have gathered more than two decades of evidence that supports the need for a significant change in the culture of chemistry education. Armed with their findings, researchers and the blue-ribbon committees have urged chemistry professors (and others in the STEM disciplines) to relinquish traditional methods of instruction and adopt teaching processes that significantly increase active student engagement (e.g., AAAS, 1990; Advisory Committee to NSF, 1996, 1998; Benvenuto, 2002; National Research Council, 2003; Wood & Handelsman, 2004). They argue that inquiry teaching and other high learner-engagement practices will increase the criteria for functional understanding, help students construct a coherent conceptual framework for complex processes and ideas, and increase student ability to reason and to see the connections among formal chemistry representations and the real world (see Abraham & Renner, 1986; Bodner, 1991; Farrell, Moog, & Spencer, 1999; Tien, Roth, & Kampmeier, 2002).

Why, then, do so many chemical educators still hold fast to traditional lecture-based pedagogies when researchers presented them with sound and rigorous evidence that traditional methods of chemistry instruction are no longer justifiable? One of the most common ways that chemistry professors rationalize their unrelenting grip on traditional teaching methods is their core belief that if traditional lecture worked for them in their undergraduate career, then it should work for other undergraduates enrolled in chemistry courses. But, does the “it work for me” argument have merit? A recent survey by textbook publishers, reported in the February 7, 2005 Chemical and Engineering News, notes that while 300,000 chemistry students enroll in general chemistry each year, only about 10,000 bachelor’s degrees in chemistry are awarded annually. Thus, the argument of “it worked for me” holds little merit considering that, year after year after year, over a quarter of a million students are unlike their instructors. The argument holds even less merit when one considers the intellectual tradition of those who use it. The bottom line is that the chemistry professoriate, on the whole, continues to teach using unexamined methods—methods based on their personal opinion and intuition regarding what is
effective. Yet, these chemistry instructors are the very scientists who demand both validity and reliability in their own scientific research (Handelsman, et.al, 2004). What is demanded of disciplinary research is not demanded of disciplinary teaching.

Noting that dichotomy of evidentiary rigor, we propose to study, learn, and work at the “heart of the matter”. At the heart of the matter are the beliefs, assumptions and reasons that underlie the decisions made by chemistry educators regarding the effectiveness of their instructional practices. We will conduct our project under the research-based assumption, that teachers do not teach in ways that are proven to be effective, rather, they teach in ways that they BELIEVE are effective (Moss, 2002; Roehrig & Luft, 2004). This approach is highly significant, because as Clevenger (2004) notes, the problem is not just that chemistry educators accept the validity of their personal beliefs regarding the effectiveness of their teaching without gathering evidence to support their conclusions; the real problem is that they often hold on to ineffective instructional practices despite being exposed to evidence that contradicts their beliefs. This particular dichotomy has been documented in educational research that examines the tenacity of beliefs about teaching and how those holding such beliefs can be encouraged to examine them through systematic and intentional inquiry (Cunningham, Schreiber, & Moss, 2005, Moss & Schreiber, 2004).

Working as a team of chemistry and educational psychology faculty, we propose to encourage and assist general chemistry teaching assistants (TAs) to reveal and challenge the beliefs that they hold regarding first, the instructional practices that they choose and second, what they accept as warranted evidence that their instructional choices result in significant student learning. In this way, we will go beyond providing new strategies and techniques and will develop capacity within the TAs to inquire constantly into their own teaching as it relates to student learning.

Clearly, it is not enough to provide chemistry instructors with the WHAT (i.e., the content). There are volumes of general chemistry texts that provide a variety of approaches to content coverage. Nor is it enough to provide the HOW (i.e., a set of techniques and strategies for teaching chemistry). Effective strategies and techniques have been proposed, described, and evaluated with only minimal effect on the culture of chemistry education. The literature of chemical education tells us that it is easy for chemistry teachers to disregard new instructional techniques and strategies and “fall back” on what they know best: traditional methods of instruction (e.g., King, 1994). As we see it, the only way to effect a significant and lasting change in the culture of chemistry education is to focus on the WHY (i.e., the beliefs and assumptions that TA’s hold regarding effective teaching). And in doing so, help TA’s see that the WHAT, the HOW, and the WHY are functionally bonded.

Our project builds on what is already known in chemical education: the WHAT to TEACH and the HOW to TEACH. On that foundation, we propose to build Paths of Inquiry whose starting point is the WHY, the heart of the matter. As will be shown in the next section, the construction of Paths of Inquiry is a community effort. As a teacher—one who seeks to facilitate student learning—each TA is a critical member of the construction crew. Each TA’s path will begin at her or his beliefs and assumptions regarding the nature of teaching and learning. The expertise required to determine those beliefs and assumptions comes from the rest of the construction crew: the chemical educators and the educational psychologists that constitute the project’s research team. That expertise will not only determine where the path starts, but will guide each TA’s inquiry as they move along a path toward significant student learning.
The Teaching as Intentional Learning (TIL) Process:
The Teaching as Intentional Learning (TIL) Process (Moss, 1999; 2000) encourages educators to view classroom concerns as invitations to learn, rather than as problems to be fixed. Moreover, the process fosters systematic and intentional inquiry into the beliefs teachers hold regarding how students learn and how effective instructional practices support that learning. Teachers do this by using relevant theory, research and effective practice to weigh the validity of their practices and their beliefs—a bond that has been identified as driving both the decisions that teachers make and the evidence that they accept that a practice is effective.

To conceptualize the process, think of a diamond shape. The top of the diamond is where the process begins as a teacher identifies a real concern from his/her teaching practice and uses that concern to begin a process of professional learning that is intimately tied to real classroom life. The TIL process encourages divergent thinking as the teacher reveals and challenges existing norms and assumptions, examines contributing factors that may form a causal explanation for the concern, and examines both decisions of practice and underlying beliefs that drive those practices. In doing so, the teacher widens the learning agenda as each new piece of learning reveals other underlying factors and therefore an ever widening path of inquiry. This part of the process is known as concern driven learning.

As the teacher reaches the middle or widest part of the diamond, he or she uses the previous learning to form a reasoned hypothesis that addresses underlying factors in a comprehensive way. Once a hypothesis forms, the teacher enters hypothesis driven learning and begins to refine the learning agenda to test the tentative causal explanation. Each refinement brings the teacher ever closer to the southern point of the diamond and encourages evaluation and decision-making.

The final phase of the TIL process is the identification of a reasoned problem—the southern point of the diamond. Now the teacher can design a course of actions that addresses the reasoned problem based.
References


Clevenger, J. (2004). American Chemical Society Division of Chemical Education, CHED Newsletter, Fall.


