University of St. Thomas: Using Modules to Teach General Chemistry

Presented by

The Institute on Learning Technology

part of the

A Project of the Wisconsin Center for Education Research

National Institute for Science Education

Funded by the National Science Foundation

Mark Connolly (mrconnolly@facstaff.wisc.edu)

Fall 2002

This case study also is available from the

Learning Through Technology web site,

www.wcer.wisc.edu/nise/cl1/ilt.

Acknowledgements: The authors thank the University of St. Thomas faculty, staff, and students who participated in this study. These individuals very graciously responded to our requests for their time and attention. This case study is based on a collaborative analysis and planning process undertaken by the NISE's Learning Through Technology "Fellows" group: Jean-Pierre Bayard, Stephen Erhmann, John Jungck, Flora McMartin, Susan Millar, and Marco Molinaro. The Fellows, in turn, benefited substantially from members of the College Level One Team: Andrew Beversdorf, Mark Connolly, Susan Daffinrud, Art Ellis, Kate Loftus-Fahl, Anthony T. Jacob and Robert Mathieu.

I. Introduction

In 1996, University of Saint Thomas chemistry professor Betsy Longley got interested in using modules to teach better. She first experimented, using modules in a limited way the following year. In 1997, Betsy decided to completely "modularlize" an introductory course (Chem 101) that she alone was teaching. Based on that experience, she persuaded her department colleagues to permit the use of modules in the three "regular" sections of Chem 111, a multi-section course that starts the curriculum sequence for chemistry majors. Data collected in 1998 from the module-based sections indicated that students performed as well on end-of-semester exams as those who took non-module sections in previous years. Despite mixed reactions to modules from both instructors and students, the module-based sections reported other salutary outcomes, including (on average) greater student enthusiasm, less absenteeism, and greater retention of content knowledge in subsequent, advanced courses.

The following year, neither Betsy nor her colleague David Boyd taught the module-based Chem111, instead handing the sections over to three of their departmental colleagues, who were somewhat less enthusiastic. When Betsy left the department—first for a maternity leave, then permanently—module-based Chem 111 lost a key supporter, and modular classes were then picked up by faculty who were either less familiar with, or supportive of, teaching with modules. Unable to sustain a critical mass of supporters during changes in personnel and class assignments, the movement to modularize Chem 111 foundered.

Not all successful educational reforms persist. Put another way, even though an innovative and effective educational approach may succeed in improving how students learn, that success is no guarantee that it will thrive or even persist. This statement may surprise some, but it is a truism among those who regularly work with groups of faculty who attempt to change their teaching practices. It happens time and time again: individual faculty members find something that works and try to share it with their colleagues, knowing that "it takes a department to raise a student." But along the way, maybe in the handoff, the innovation loses steam, something goes awry, and the innovation dies on the vine. In some cases, when the original innovator loses heart or has her innovation repudiated—sometimes through benign neglect—the innovation dies completely.

Why don't successful innovations "stick?" That question is the focus of this case study. Although the eight other LT^2 case studies have explored in great detail what makes their bricoleurs' instructional innovations not only succeed but persist, this case study is different. Here, we present a kind of cautionary tale that suggests that the toughest part of reforming undergraduate science education is not about innovating but finding ways for innovations to survive.

The case we'll be studying concerns the use of modules by Professor Betsy Longley to teach general chemistry at the University of Saint Thomas (UST) in St. Paul, Minnesota.

It is important to note right away that, in presenting this particular case, we do wish to cast aspersions upon the credibility or effectiveness of modules in teaching chemistry. Indeed, evidence collected by Betsy and her colleagues (that we will examine later) suggests that her modular approach had salutary effects on students' motivation and acquisition of chemistry content knowledge. Moreover, findings from scholarly studies support claims for the effectiveness of using modules to improve how and what students learn (see, for example, Anthony, Mernitz, Spencer, & Gutwill, 1998; Gutwill-Wise, 2001).

So our point here is this case is not about the efficacy of the modules *per se,* because they worked for awhile at UST, and they work elsewhere.[1] We did not pick UST *a priori* as a case of an innovation ***not*** catching on. In using the same criteria as the other cases to select the University of Saint Thomas and Betsy Longley, we fully expected to describe the same kind of successes told in of cases at Joliet Junior College, University of Michigan, and University of Illinois at Urbana-Champaign. However, in the time between UST's selection as a case site and our composing this case study, the use of modules by the chemistry department at UST experienced a reversal of fortune. Based on our correspondence with key respondents involved with the case, we learned that modules will not be used to the same extent as they were at the time the case was selected. Believing it would be disingenuous to represent UST's use of chemistry modules as exemplary (which is a key purpose of these cases), we've chosen instead to illustrate why some reforms do not persist in spite of their efficacy. Our reason for this choice is that unsuccessful experiments often hold important lessons.

In short, the story is this: Betsy Longley becomes interested in chemistry modules through ChemLinks, and begins using modules in her own class. She takes to her department colleagues the suggestion that modules might be used to teach a multi-section course of general chemistry, and they express some interest, based in part on the argument she makes and the evidence she provides. Over the next year, Betsy and other chemistry professors use modules to teach general chemistry. They attempt to gather evidence for evaluating the modules against their instructional goals, and their use of modules is also studied in an evaluation study by Elaine Seymour and her colleagues. However, at a crucial stage in the spread of this innovation, Betsy is granted a maternity leave, leaving others to teach the course in which she had effectively used modules. Also, a colleague of hers who had used modules becomes the chair of the department, and must now devote more time to administrative responsibilities. In the time since Betsy's absence from the department in 1999, the department's interest in using modules flags significantly. Despite evidence that students were learning better with modules in Betsy's class (as well as other evidence in scholarly literature for the advantages of modules), the department has consigned chemistry modules to a kind of benign neglect. For a number of interrelated reasons—namely, divided faculty opinions about the value of modules, mixed student reactions, sections taught by faculty inexperienced with modules, and the departure of the modular approach's "idea champion"—the chemistry department at UST has decided to significantly reduce its use of modules.

The purpose, then, of this case is to analyze a situation where an instructional innovation did not catch on. First, we describe the case context, providing some background on the institution and the department. Then we describe the course of events involving the use of modules in UST's GenChem course—namely, how it was introduced, implemented, and what led to modules not being used. Finally, we provide some analysis of the case and suggest lessons that might be drawn from it.

Information on how this case and other LT^2 cases were chosen and the methods used to gather data used for these case studies is presented in the Case Studies Overview <http://www.wcer.wisc.edu/nise/cl1/ilt/case/case.htm> and in the Resource called "Methods Used to Conduct This Case Study."

II. Institutional Setting

The institutional setting for this case is the University of Saint Thomas in St. Paul, Minnesota. With an enrollment of nearly 11,000 students, UST is Minnesota's largest independent institution. As its name change from the College of Saint Thomas in 1990 might suggest, UST is an institution in flux—trying to hold onto its heritage as a Catholic liberal arts college while expanding and reorganizing to meet a major metropolitan area's growing need for professional and graduate education. St. Thomas now offers 45 graduate programs, most of which have been established during the past 20 years; its graduate school of business enrolls more than 3,000 students, making it the fourth-largest graduate business school in the U.S. At an institution that sees itself as being a Catholic liberal-arts college, roughly a third of its undergraduates are business majors. The College began admitting women in 1977, and women are now (2001-2002) a majority of its students (54%). Graduate students, most of whom attend part time, now make up more than half of the institution's total enrollment (5,600 of 11,000 students). St. Thomas currently employs approximately 380 full-time and 400 part-time faculty.

The Department of Chemistry at St. Thomas

Currently, the UST Department of Chemistry offers only an undergraduate curriculum, leading to either a BA degree or an American Chemical Society-certified BS degree, the latter being recommended to students planning on graduate study or advanced research in academic, industrial, or government laboratories. St. Thomas also offers a BS in biochemistry, which is an interdisciplinary program that draws upon faculty and courses from the Departments of Biology and Chemistry.

The Department of Chemistry includes between 12-14 full-time faculty and 2 support staff. Its faculty specialize in such areas as organic chemistry, inorganic chemistry, analytical chemistry, physical chemistry, and polymer chemistry. On average, the department has about 15 majors.

The department is housed in a building opened in 1997 with the very latest laboratory designs, equipment, and instrumentation. While it is an advantage to the chemistry faculty to have such modern facilities and equipment, they also feel a subtle pressure to use such resources to do more and better research. As Dean of the [Undergraduate] College, Tom Connery, pointed out, there is a tacit expectation of the institution, placed in turn on the chemistry department, that "you've built this state-of-the-art science building . . . make sure you do something with it."

The course that is the focus of this case study is Chemistry 111, which is described in the UST catalog as this:

> *CHEM 111 General Chemistry I (100) 4 credit(s)*
>
> *This course and its sequence 112 provide a two-semester introduction to chemistry. Topics include atomic structure, molecular structure, chemical bonding, the periodic table, states of matter, reactions (types, energy changes, equilibrium and rates), properties of the common elements and their ions in*

aqueous solution, electrochemistry and nuclear chemistry. Lecture plus four laboratory hours per week. Prerequisite(s): Math placement at 108 or above; if placement is lower than 108, registration must be for section 31 (extended).

This course is the first in the curriculum sequence taken by chemistry majors. It enrolls approximately 250 students the semester it is taught. Scores on a math exam are used to place students. The top 20 students are put in an honors section, and the bottom 20 students or so who don't make the cut score must enroll in a special section that meets during the January session, between Fall and Spring semesters; this additional section gives students more time to work on study skills and math skills. The remaining students are placed in 3 sections of roughly 75 students each, thus giving Chem 111 a total of five sections.

III. Description of the Instructional Innovation

What exactly is a "module," and what makes teaching with it different from traditional teaching?

"Modules" are computer-based instructional units organized around a question about a particular phenomenon that (a) students are expected to have some prior understanding of, and (b) can provide a context for introducing and understanding scientific concepts. For example, one module developed through the ChemLinks Coalition and the Modular Chemistry Consortium (MC^2) is based upon a device nearly indispensable to college students—the compact disc player—and asks whether, by getting blue light from a solid, one could design a better CD player. As the module description explains,

> *This module challenges students to think about a materials design question, how to get light out of a solid, during two to three weeks of their chemistry course. Light-emitting solids are essential for many high-technology materials and products, including compact disc (CD) players. Students make use of the periodic table to propose color-specific emitting solids based on knowledge of periodic properties, bonding, electronic transitions, solid structures and the properties of light. (from http://mc2.cchem.berkeley.edu/modules/bluelight/)*

Thus, the "blue light" module, as it's known, provides a different way of teaching periodicity and bonding as well as forms of scientific reasoning: recognizing trends, making logical inferences and deductions, and interpreting graphs.

Similarly, a module that uses automobile air bags to study gas laws asks, "Can fast, gas-forming reactions save lives?" The following description of the "air bag" module explains the areas of chemistry and practical skills students will be expected to learn:

> *The development of airbag systems for automobiles will be used as a case study for introducing a variety of chemicals and chemical formulas, how to determine mass/mole relationships, and how to carry out gas law computations. Other concepts such as heats of reaction and kinetics will be introduced, but only to the extent necessary to understand their importance in airbag design. Problem solving, assessment of relative risks, and trade-offs in the design of airbag systems will be explored. (from http://mc2.cchem.berkeley.edu/modules/airbag/)*

However, using modules is more than just providing good, concrete examples (like CD players and air bags) to explain chemical concepts. Rather, modular instruction involves significant changes in both *curriculum* (the content and organization of the course) and *pedagogy* (the course's teaching- and learning-related activities).

How modules can change the traditional chemistry curriculum

Traditionally, the introductory chemistry curriculum has consisted of breaking chemistry content knowledge into relatively discrete topics, such as stoichiometry[2], periodicity[3], gas laws, kinetics, and so forth. The curriculum consists of leading students from topic to topic, chapter to chapter[4]. However, because modules teach chemistry through understanding and solving real-world problems, such as global warming or ensuring a safe water supply, a module-based curriculum is not a march through the standard chemistry topics. Instead, an introductory course may include 3-5 modules, each of which "typically spans 3-4 weeks of class time and utilizes a single real-world topic as a vehicle for teaching a coherent set of chemistry concepts" (Gutwill-Wise, 2001). So, rather than learning stoichiometry and mole equations when they come to those chapters in the conventional curriculum, students learn about those important concepts and skills through Session 6 of the global warming module, titled "What Are Your Personal Contributions to Greenhouse Gas Emissions? Moles and Stoichiometry." The goals for this section are described here:

> *You will use laboratory investigations and stoichiometric calculations to determine whether you personally are a significant source of greenhouse gases. You will examine your daily activities to estimate which have the greatest impacts on greenhouse gas levels. For instance, are you responsible for more carbon dioxide emissions if you drive to Boston or fly? Balancing equations, mole calculations, stoichiometry, unit conversions, experimental design, and order of magnitude are skills that will be developed during this session. (Anthony, Brauch, & Longley, 1998).*

Thus, not only do students learn the skills and concepts associated with calculating mole equations, but students also learn or use other important skills such as scientific reasoning, problem solving and troubleshooting experiments, marshaling evidence to support a claim, and effective communication (oral, written) of methods and findings. Modules lend themselves to fostering the kinds of knowledge, skills, and attitudes that are expected of scientific literacy that is characteristic of the kind of liberal arts education UST wishes to offer its students.

How modules can change teaching methods

Using modules necessitates not only curricular changes but changes in conventional teaching methods. Traditionally, introductory chemistry courses are taught in a lecture-lab format; students listen and take notes during the instructor's lecture, then participate in a smaller laboratory experience that allows students to practice using equipment while conducting what are essentially verification laboratories. However, to encourage the kind of intellectual engagement that characterizes modular-based classes, instructors must do more than lecture. Thus, instructors use teaching methods that foster what is called **active learning**—which requires more than just listening (e.g., writing, discussing, questioning), but also engaging in higher-order cognitive activities such as synthesis and evaluation.[5]

A second major pedagogical feature of modular classrooms is **cooperative learning**, which is defined by Roger T. Johnson and David W. Johnson as "a relationship in a group of students that requires positive interdependence (a sense of sink-or-swim together), individual accountability (each of us has to contribute and learn), interpersonal skills (communication, trust, leadership, decision making, and conflict resolution), face-to-face promotive interaction, and processing (reflecting on how well the team is functioning and how to function even better)."[6]

A third feature of modules is **inquiry-based laboratory projects**. Rather than doing traditional verification labs (that is, following the steps of an experiment in order to achieve a predetermined outcome), students work in teams to solve a problem and are expected to use a combination of problem-solving skills, subject-matter knowledge, and technical lab skills in a way that resembles actual scientific research.[7]

Modules and the UST Chemistry Department—"Getting Going"

From 1995 until 2001, Dr. Betsy Longley was an assistant professor of chemistry at the University of St. Thomas. After arriving at UST with a Ph.D. in physical chemistry[8] from the University of Pittsburgh, Betsy attempted to use modules to improve how the majors in her Chem111 class learned chemistry.

Modules provided Betsy with the means to link her classroom with the "real world," so to speak. Whether it was using a computer program to adjust the chemical composition of an air bag to ensure it inflates safely or using an "IR tutor" to demonstrate how molecular bonds bend or stretch when absorbing infrared radiation, Betsy relied on different types of technology to construct and deliver her modules; instructional multimedia allowed her "to do or see something that is otherwise impossible, dangerous, expensive, or too time-consuming" (Anthony, Mernitz et al., 1998). And, according to Betsy, her students found that technology enabled them to do two things much better: visualizing otherwise abstract concepts, and manipulating chemical phenomena and relationships. And from the institution's point of view, another important outcome of Betsy's students' using modules was that they were becoming more adept at using technology to solve problems and present their findings.

Betsy's motivation for introducing this kind of technology into her classroom stemmed from her concerns about traditional chemistry education for non-majors, which are discussed below. Betsy used a simple formula to drive her efforts: greater student engagement equals greater student learning. Thus, because she believed she could help students learn chemistry better if it is somehow connected to their personal experience, she used modules to "real them in"—that is, using *real*-life examples like automobile air bags, global warming, compact-disc players, and dietary fats *to reel students in*, drawing them into a deeper understanding and appreciation for chemistry.

Learning "Problems" As Betsy Saw Them

Improving one's teaching and its effects on students' learning seldom occurs simply "for the heck of it." Rather, the process of analyzing one's teaching practices usually begins with some sort of knotty problem, some sort of dilemma that frustrates or intrigues the instructor. So it was with Betsy, who faced a number of persistent "problems," or issues related to her students' learning.

<u>Boredom</u>. Betsy found that relying on traditional methods of teaching introductory chemistry simply left students bored. Boredom by itself was not the problem; the learning problem arose when bored students become disengaged and uninterested, leaving only the most motivated and disciplined students to press ahead and do whatever was necessary to satisfy course requirements.

And even then, persistence in the face of boredom was no guarantee that the students succeeded in gaining any kind of deep learning of chemistry.

Not accommodating diverse learning styles. Betsy was also concerned about the *student disengagement* that resulted from instruction that didn't accommodate multiple learning styles.[9]

Teaching science to non-majors. Betsy was an undergraduate chemistry student at Hamline College, which is another liberal arts college in St. Paul. Betsy's own liberal arts undergraduate education may help explain why it is so important to her that students who take her Chem 111 to satisfy St. Thomas's general education requirements have a positive experience with science. As Betsy put it, "If they're going to have only one science course, I want it to be a good experience." Rather than seeing this course as just a bureaucratic requirement, she instead sought to fulfill the ideal of a well-rounded liberal arts education, which includes a basic understanding of some kind of science:

> *We have probably two hundred students, and maybe ten of them will go on to be chemists. The other 190 won't, and a majority of them might not even go into science. I think, "Well, this is their one science class and they're going to go out and be whatever they might be—professionals in economics or business. I want them to know what science is about." I don't want my General Chemistry class to be focused only on teaching them these topics so that when my colleague gets them in Organic, they're prepared for that . . . because they might not ever go there.*

Instructor dissatisfaction. As Betsy points out, classes that are boring for students can be just as boring and uninteresting for those who teach them.

> *[Teaching with modules]—it's just so much more fun for me. I just enjoy it much more, it's a more real thing. My enthusiasm is more genuine, I would say. I'm learning from it. I would say Blue Light was probably the one that was most like this. I just learned a lot from it.*

UST's Involvement with ChemLinks

In March 1996, shortly after being hired at St. Thomas, Betsy attended a Project Kaleidoscope[10] workshop at Columbia University:

> *I met Brock Spencer [professor of chemistry at Beloit College and principal investigator for the ChemLinks Coalition, one of five National Science Foundation Systemic Change Initiative in Chemistry projects] there and got interested. That was in March, and he asked me to attend their MC^2/ChemLinks joint meeting, which happened to be in St. Paul that year, the next month. So I went over to Macalester College, just down the road one mile, and got very excited about it.*

As a result of attending this workshop, Betsy began thinking about what she might do to improve her students' learning. One step was articulating her aims of an improved Chemistry 111—namely, she believed she could improve her students' learning if she (1) made chemistry more interesting to them and (2) made greater use of technology in the classroom.

1. Tinkering with Modules

Through her involvement with the ChemLinks/MC[2] consortia, Betsy learned about teaching with modules and got excited about the possibility that this different instructional approach might help her address her classroom concerns of boredom, relevance and engagement. So she started tinkering with her own classes during the 1997 academic year:

> *What would have been the next thing that I did? I think I toyed a little bit with teaching little pieces that next fall, or that spring–I guess I'm getting all my dates mixed up. But then we had a February Valentine's meeting at Grinnell, and at that point, I became a co-author on the Global Warming module. So I was just starting with P. Chem., but then was just kind of getting involved with that group. So then I've been going to the joint meetings ever since. The following year it was in Berkeley, then back in Minnesota.*

She first used only one module on global warming (one she helped write) in all sections of Chem 111 in 1997. The following year, she started teaching Chem 101 (an introductory course that focuses on applications of chemistry to environmental science) on her own and as a "fully modular" course.

> *When I did it the first time around in the Environmental Chemistry, there's only one section of that class. It's not for majors, and those courses, at least in our department, nobody except the person who's teaching them really pays any attention to what's happening. I probably could have taught Shakespeare in that class, and people might not have noticed. So, I took that opportunity to jump in and do the modules, a fully modular course. I didn't need to ask permission, in a sense.*

2. Expanding Teaching with Modules to the Department

After a semester of working through the kinks of teaching a fully modular course, Betsy saw that modules could be an effective way of making other courses in the UST chemistry curriculum more engaging. So she pitched to her departmental colleagues the idea of using more modules in the Chem 111-112 sequence:

> *When we thought about doing it in Gen. Chem, there was the discussion of "Oh, should we make some improvements in Gen. Chem" that has been going on for years. We meet each summer for two days off campus for retreat. When we have these kind of long term planning discussions. I guess, I just suggested it. I said "Let's try what I just did in Environmental, let's do this in Gen. Chem."*

Some of her colleagues were interested, and some less so. But they managed to agree as a group to try it for two or three years.

During the 1998-99 academic year, four of five sections of the Chem 111-112 were taught entirely with modules. Betsy and her colleague David Boyd each taught one "standard" section of Chem 111 and 112, and the other two sections (one standard and one extended) with modules were taught by two different, non-tenure-track faculty (one in a one-year position, the other in a five-year limited term position). The fifth section for honors students was taught by a tenured faculty member who neither supported nor used modules.

3. Chem 111 modules: Fall semester 1998

During that semester, Betsy and the others taught Chem 111 using just four modules: global warming, airbags, fats, and blue light. (For more information on each module, visit the accompanying web site.)

global warming (http://chemistry.beloit.edu/Warming/index.html)

airbags (http://mc2.cchem.berkeley.edu/modules/airbag/)

fats (http://mc2.cchem.berkeley.edu/modules/fats/)

blue light (http://mc2.cchem.berkeley.edu/modules/bluelight/)

4. What the class looked like

In the appendix, you will find a copy of the Fall 1998 Chem 111 **syllabus** used by Betsy and David.

Reviewing it, you'll see that, apart from the use of modules, a difference between the "old" Chem 111 and the modularized version was the introduction of **learning journals**, in which students were expected to reflect upon their learning experiences and help Betsy understand the highs and lows of learning chemistry with modules.

Another crucial piece to modularizing Chem 111 was providing students with all the instructional materials they needed without overwhelming or disorienting them—which meant using the conventional text *and* the module student guides. (Later sections used **a customized text** from Wiley Publishers that attempted to combine both the text and the module student guides.)

Students were given CD-ROMs that accompanied their texts. These **module web tools**, also published by Wiley ChemConnections, included the materials for eight modules—three of the four for Chem 111 (excluding airbags), and five that could be used in Chem 112 the following semester ("computer chip," "stars," "ozone hole," "water treatment," and "origin of life"). The CD-ROM could be used on both Windows and Macintosh platforms.

5. A typical day in Betsy's class

Here, Betsy provided a glimpse of what module-based instruction in her class looked like:

> *We start out by asking, "How many of you have ever been in an accident, or been in a crash where an airbag deployed?" In each class there was at least one person. So we'd have that person describe what happened. Then we'd go into the videos–there are some animations on the CD. So they really connect with what they already know and what's meaningful to them.*
>
> *We learned that the first day of the module is critical. We learned that it is critical how you set the stage, how you phrase the question. If you start out the module by saying, "We're about to do the Air Bags module now. Let's start with section 1A and do it,"– that's kind of an extreme example, but that type of approach doesn't do it. You really need to kind of reel them in. "Find a hook," we would*

call it. And we learned that we needed to find our own hook. The first part of the modules is written to kind of create a context, but reading this text is not really how do you reel them in.

For example, for global warming, this is how we reeled them in. The U.S. Senate has not yet voted to ratify the Kyoto Protocol, which says, "Yes we'll reduce these emissions." So I stared out, I brought in a computer and there's a web site that has a running up-to-date list of which countries have ratified this. So I brought in the computer, went to that web site and said, "Let's look at these countries." I had first described what the Kyoto Protocol was, but only in a sentence or two, since they already know about global warming. We looked at these countries– there were eighty, I think, at the time. There were some comments, like "Oh, I've never heard of that country."

We got to the end and we said, "What are some things that you observed?" There were various observations, but somebody always noticed, "Well, the United States isn't on there. Why are all the other countries, the so-called big countries on there and the U.S. isn't?" And it worked in all three classes. They are the ones who noticed that U.S. is not on there. And after they said, "Why isn't the U.S. on there?" we said, "Let's find out. What might be the reasons why the U.S. might not have yet moved to ratify it? What might be the reasons why some people want to, some people don't?"

We told them on the first day that "you will have some power persuasion at the end of this module. You'll be writing a letter to your Senator urging them to ratify or not ratify." So, we didn't decide as a class, we left it an individual decision. And getting back to your question as to why do I do this – that's one reason. One neat thing about that is that none of them had ever written a letter to their Senator. They thought it was just kind of a phony assignment. I said, "No, this is real. You're going to mail it to Congress." Many of them didn't know who their Senator was, or if they're from Iowa, or Missouri, whether they needed to mail it to a different Senator. I really liked the fact that chemistry was not such an isolated discipline then. There was a connection to things outside of chemistry. And they liked that too, I think.

6. Summary of how modules were used in Chem 111

Because modules can be used by an individual instructor in different ways and to different degrees, here is a summary of the ways in which Betsy and David used modules in their classes.

- Modules are a supplement to, not a replacement for, the text (Chang, 1998).
- Modules provide a framework for a guided inquiry approach to learning.
- A given module is centered around a relevant, interesting question.
- Modules make use of active learning/teaching.
- Modules attempt to integrate class and lab into one course experience.
- Most conventional chemistry content remains in the course; some additional content is added.

- In-class lecturing is used.
- In-class problem solving (i.e., homework) is used.
- End-of-module exams replace end-of-unit exams.
- The final exam from previous years is used.
- Modules are intended to be adapted (that is, the instructor chooses how heavily to focus on the module question and how extensively to incorporate module activities into the course).

IV. Evidence of Improved Student Learning

To gather evidence of the effects of modules on student learning in Chem 111 (Fall 1998), Betsy and David used various sources:

- UST's end-of-semester "generic" course evaluations;
- a special end-of-semester General Chemistry survey;
- data gathered as part of two evaluation studies (one by University of Colorado-Boulder, another by University of California-Berkeley) of modular chemistry; and
- instructor observations (described below).

In addition, individual exams were modified to correspond with the modules, but final exams for modular Chem 111 remained the same as before.

Here are some of the findings that Betsy drew from the data above:

- Final exam scores generally remained the same as "pre-module" courses, even though less content was covered.
- It appears that "carry forward" (the transfer of knowledge) to the next class was much improved.
- The increasing use of technology in UST classes reinforced to Chem 111 students that "everyone is learning to use technology" and that they need to learn to use it, too.
- Using technology to teach was much easier with non-majors than majors, and with first-year students than with upper-division students.
- Class participation increased, and absenteeism decreased in comparison with previous years.

- Labs that linked to modular sections involved lab instructors (who do not teach the course) to a greater degree than labs not linked to modular sections.

- Nearly all lab activities were new, and not all were tested thoroughly in advance. Fall semester labs in particular were not as prepared as instructors would have liked.

- Class and lab instructors held a range of opinions about teaching with modules.

V. UST's Implementation of Chemistry Modules: A Denouement

In Fall semester 1999, the year after Betsy and David taught Chem 111 using modules, neither one taught the class—Betsy instead taught Physical Chemistry, and David took a sabbatical leave. Again, five sections of Chem 111 were offered. Two sections were taught by two faculty new to UST (both in one-year sabbatical replacement positions) and unexperienced with teaching with modules. A non-tenure-track faculty member who taught the extended section the previous year taught the third regular section. An adjunct instructor, familiar with UST but not with teaching with modules, took the extended section, and the honors section was taught by the same tenured professor as the previous year.

The three "regular" sections of Chem111 were then taught by other UST faculty. More important, the responsibility for coordinating the General Chemistry courses was reassigned by the chair from Betsy to the faculty member in the five-year position. However, this individual did not buy into the module system and did not attempt to keep the general chemistry instructors moving forward with the development of a modular approach. Moreover, one of the sabbatical replacement instructors refused to present any module-based material and even spoke ill of the materials in front of the class. Consequently, student dissatisfaction became a persistent issue, and the gains made in Year One (1998-99) by Betsy and David were generally lost during Year Two (1999-2000).

Beginning Fall 2000, Betsy took a maternity leave from the chemistry department, and David took over coordinating the general chemistry sections. The three regular sections were taught by David, the five-year appointee, and a new sabbatical replacement instructor, and the other two sections were taught by the same faculty as the previous year. David and another instructor taught two of the regular sections as they were in 1998, and although the instructors found themselves still fighting against student expectations, it was nonetheless a good year for using modules. Within the department, faculty were still divided over whether the modules were effective and worth the trouble.

By Fall 2001, the chemistry department—unable to agree on whether to "go modular"—struck a compromise for the sake of damping departmental conflict and stress. Rather than complete its original plan for a three-year test of modules, the department instead used the modules as a kind of capstone experience in all five Chem 111 sections.

In the course of writing up this case study, we attempted to contact Betsy and learned she had opted not to return from her leave and subsequently resigned her position at UST. We then contacted David Boyd—now the department chair—and he reported that because some members of the department held strong feelings about the use of modules, it was not likely that modules would be used in subsequent offerings of Chem111 as extensively as was originally proposed by Betsy.

VI. Summing Up: What This Can Tell Us about Instructional Innovation

Effecting sustained curricular and pedagogical reform—such as modular chemistry—is more difficult than simply implementing a new approach. Efforts to innovate often don't catch on—not because they are ineffectual but because the innovation fails to spread and take hold. There is nothing unusual about the chemistry department at UST in this regard; at other institutions, instructional innovations flourish and fade all the time. In the case of UST, however, it simply happened that *someone was watching.* That is, fully expecting that modular chemistry would persist at UST, we studied the trajectory of an instructional innovation that simply did not, so to speak, achieve escape velocity.

Without gathering more data (e.g., by interviewing members of the Chemistry Department again), we can only speculate about the reasons *why* modules did not catch on in the UST chemistry department. Based on (1) what we already know about the use of modules at UST (interviews and observations during 2000) and (2) our experience studying the dissemination of innovations in pedagogy and curricula, here's what we see:

Loss of the innovation's "idea champion." Perhaps more than any other factor, Betsy's departure from her role as modular chemistry's key supporter and organizer jeopardized the approach's long-term prospects. In his study of how innovations spread, Rogers (1995) points out that successful and durable innovations are frequently propagated by enthusiastic and charismatic supporters who throw their weight behind the innovation, thus counteracting the resistance or indifference a new idea can arouse in an organization. Sometimes, innovations will become linked with those innovation champions, and when that individual will not or cannot continue to advocate for the innovation, it simply declines or disappears. Review of the other LT^2 cases provides strong evidence for the importance of this factor.

The myth of the instructional hand-off. Faculty often believe that teaching methods are like recipes and can be handed from one to another, their success depending only on how well one follows the directions. However, as Parker Palmer (1993; 1998) points out, teaching is more than technique—it is a manifestation of the teacher's knowledge and passion, and can no more succeed as a "hand off" than can other intimate human activities, such as falling in love or being a parent. The methods have to fit the individual's personality and aims, and be responsive to working with many different kinds of people. Although it is not clear from the data in this case, it appears that the department believed that modular chemistry could be handed off from Betsy to other teachers in the department as long as they followed the "recipe."

The pitfalls of moving from pedagogical to curricular reform. Where professors often get tripped up is moving from issues of teaching to issues of curriculum. Shifting from pedagogical innovation to curricular innovation can politicize the change (Kozma, 1985). Another characteristic of this case similar to others we have seen is what happens when a key innovator who is doing innovative teaching on her own tries to involve her colleagues. Inevitably, the pedagogical becomes curricular, and suddenly the unsuspecting person has wandered into a quagmire of unseen issues and deeply held opinions. Although many faculty may not worry about how others may teach (considering it to be an individual matter), trying to change the curriculum can awaken deep divisions of opinion that are otherwise papered over in the name of collegiality.

The advantages of "tinkering" with one's teaching. In a study of faculty who tried changing their teaching practices, Stevens (1988) found that the most successful faculty tended to "tinker" with their teaching—that is, they changed their teaching in small and manageable ways rather than on a large scale. Stevens also described two different kinds of "tinkerers": reactive and reflective. Reactive tinkerers tended to change their teaching to solve a particular problem by adopting a technique or trick (e.g., trying "think-pair-share" activities with seemingly bored students), and when the technique didn't work, the reactive tinkerers tended to give up. However, the reflective tinkerers that Stevens studied tended to tinker regularly, seeking not necessarily to solve problems but to engage in a kind of continuous improvement, knowing that one never solves instructional problems permanently and for all groups. Moreover, reflective tinkers tended to rely not on others, but on themselves, as creators and evaluators of instructional innovations.

By analogy, we might say that reactive tinkerers are like computer users who run into a problem and download a utility that they expect to help them. If it solves their problem or meets their need, then great, they press ahead. But if it doesn't, they uninstall it and either give up or search for something else. Reflective tinkerers, on the other hand, see teaching as "open-source code" and themselves as programmers with a capacity for building their own innovations. And although they too may borrow tools and utilities that others have made, they are willing to "reverse engineer" an approach that doesn't work and perhaps use it in a different context. As with computing, those who can construct and evaluate their own approaches have greater flexibility (and perhaps satisfaction!) than those who must rely on programs or applications devised by others that may or may not accommodate their particular circumstances.

VII. References

Anthony, S., Brauch, T. W., & Longley, E. J. (1998). *What should we do about global warming? [Beta version of student manual].* New York: John Wiley & Sons.

Anthony, S., Mernitz, H., Spencer, B., & Gutwill, J. (1998). The ChemLinks and ModularCHEM Consortia: Using active and context-based learning to teach students how chemistry is actually done. *Journal of Chemical Education, 75*, 322-324.

Grasha, A. F. (1996). *Teaching with style: A practical guide to enhancing learning by understanding teaching and learning styles*. Pittsburgh: Alliance Publishers.

Gutwill-Wise, J. (2001). The impact of active and context-based learning in introductory chemistry courses: An early evaluation of the modular approach. *Journal of Chemical Education, 78*, 684-690.

Kozma, R. B. (1985). A grounded theory of instructional innovation in higher education. *Journal of Higher Education, 56*, 300-319.

Palmer, P. J. (1993, November/December). Good talk about good teaching: Improving teaching through conversation and community. *Change, 25*, 8-13.

Palmer, P. J. (1998). *The courage to teach: Exploring the inner landscape of a teacher's life*. San Francisco: Jossey-Bass.

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

VIII. Resources

A. Methods used to produce this case study

During November 1999, Betsy Longley and the University of Saint Thomas chemistry department were identified as candidates for a case study on interesting teaching and learning practices that in SMET courses use computer-based technology to enhance learning.

In late February 2000, two fellows from the National Institute for Science Education's Institute for Learning Technology—Flora McMartin and Jean-Pierre Bayard—visited the UST campus to talk with Betsy and her colleagues and to see what happens in their classes. Flora and Jean-Pierre interviewed six members of the chemistry department: former Chair Lynn Hartshorn, John Bergman, current Chair David Boyd, Rich Roberts, Tim Zauche, and Betsy Longley (whom they interviewed twice). In addition, the fellows interviewed Tom Connery, the Dean of the Undergraduate College, Pam Guernara, a staff member from Instructional Support Services who works with chemistry faculty, and two groups of GenChem students. Finally, Flora and Jean-Pierre observed both Tim's and Rich's sections of GenChem.

The interviews were guided by the protocols used in all the Learning Through Technology case studies and were audio-taped and transcribed. The interviews and other data sources (e.g., classroom observation notes, syllabi, module handbooks) were compiled and analyzed by Mark Connolly. With assistance from Susan Millar, Sharon Schlegel, and Andy Beversdorf, Mark also composed the UST case study.

Acknowledgements:

The authors thank the University of Saint Thomas faculty, administrators, staff, and students who participated in this study. These individuals very graciously responded to our request for their time and attention.

This case study is based on a deeply collaborative analysis and planning process undertaken by the NISE's Learning Through Technology "Fellows" group:

Jean-Pierre Bayard, bayardj@csus.edu
Stephen Erhmann, ehrmann@tltgroup.org
John Jungck, jungck@beloit.edu
Flora McMartin, mcmartin@needs.org
Susan Millar, smillar@engr.wisc.edu
Marco Molinaro, molinaro@scienceview.berkeley.edu.

The Fellows, in turn, benefited substantially from members of the College Level One Team:
Susan Daffinrud, daffinru@engr.wisc.edu

Art Ellis, ellis@fozzie.chem.wisc.edu
Anthony Jacob, atjacob@facstaff.wisc.edu
Kate Loftus-Fahl, skloftus@facstaff.wisc.edu
Robert Mathieu, mathieu@madraf.astro.wisc.edu.

Appendix

Chem 111 Syllabus: Fall 1998

GENERAL CHEMISTRY

Chemistry 111

Fall 1998

Course Information and General Procedures

Members of the class are responsible for the following information and are expected to comply with all procedures stated in this document.

Section	Instructor	Office	Telephone	Email	Office Hours*
01	Dr. Craighead	454 OWS	962-5583	klcraighead	M,W 3:00-4:30; F 10:30-12:00
02	Dr. Longley	455 OWS	962-5574	ejlongley	M,T 1:30-3:00; F 8:30-9:30
03	Dr. Boyd	457 OWS	962-5577	dcboyd	T,Th 1:30-3:00; F 12:00-1:30
31	Dr. Roberts	461 OWS	962-5592	reroberts	

*or by appointment

Messages may also be left with the Science Division Secretary (402 OSS, 962-5575) if absolutely necessary.

Course Materials

Each student must purchase the required course materials at the university bookstore. This includes the course modules, the reference textbook (*Chemistry* by Raymond Chang), a composition book, and the official lab notebook. In addition, each student will need an electronic calculator (an inexpensive model with logarithmic and exponential capabilities is sufficient).

Course Components

The semester will be divided into four modules, each focusing on the chemistry of an issue drawn from the world around us. Three of these modules will end with a written examination. Each module will also include a culminating project such as a debate or a formal laboratory report. You will find a schedule for each unit elsewhere on the web site describing the reading and homework to be done in preparation for the lectures. ***Daily class preparedness and participation is expected of every student!***

In addition to the hour exams, a 150 point cumulative final examination will be given during finals week. More information and study aids will be provided near the end of the semester to help you prepare for the final.

A variety of written work including problem solving, small group exercises, and journal entries will be assigned during the semester.

Each student will be asked to keep a journal consisting of a minimum of three entries per module describing your thoughts on questions or readings posed by the instructors. Each entry should be at least one page in length written in a composition book bearing your name on the front cover. This journal will be reviewed periodically by the instructor. This is an open forum for discussion and the exchange of ideas (whether we agree or not), as well as a way of telling your instructor about yourself, your experiences, your interests and your dreams. The journal has proven itself as a great way for students to get to know their instructor, and will only be beneficial if you put time into it as you would any other assignment.

Finally, each student must attend his/her designated laboratory period each week. Due to space limitations, you **must** attend the laboratory section for which you are registered.

Attendance

Students are expected to attend all lectures and laboratories. Excessive absences may result in grade penalties at the instructor's discretion. An excused absence requires written official documentation from an appropriate administrator such as the Dean of Students or the Health Service. In the event of an excused absence, it is the student's responsibility to fulfill all course work. Note that laboratories may only be made up within the assigned week for the experiment regardless of whether an absence is excused or not.

Lectures will begin promptly at the beginning of the class period, so plan on being seated and ready to go. Late arrivals are quite disruptive to the class and usually result in a poor experience for the late student as they have missed the announcements and introduction to the topic. Please be on time!

Laboratory Work

A complete list of laboratory information may be found in the introductory lab materials. Please read this information carefully before the first day of laboratory work.

The laboratory component is mandatory, and failure to successfully complete the laboratory exercises automatically results in failure of the course. Laboratory work is to be performed **only** on the day for which you are registered.

Laboratory reports are due **at the beginning** of the lab period the week following completion of the experimental work. Late lab reports will not be graded.

Student Disabilities

Students with documented disabilities who may need classroom accommodations should make an appointment with the instructor as early as possible, no later than the first week of the semester.

Study Schedule and Habits

Your attitude toward what you are doing is just as important as the efforts that you put forth. It is crucial that you realize you are not just studying for an isolated module exam, but rather laying a foundation of general knowledge, developing problem-solving skills, and forming study habits that will impact all subsequent modules. The entire year is something of a pyramid in that ideas studied today become the basis of future discussions. In fact, the final exam for CHEM 112 (offered in the spring semester) will be a cumulative standardized exam encompassing both semesters. This may sound intimidating now, but will actually seem quite reasonable in May.

It is essential you study chemistry on a daily basis if you are to succeed at integrating new material with older material. Daily study will help your retention, comprehension, and basic study and problem-solving skills. You will find success in this course very difficult (or nearly impossible) if you study on an irregular basis. In many cases attitude is more important than natural ability and there is no substitute for hard work and perseverance. Crisis to crisis studying will never lead to retention of important material, and such a routine will prove disastrous for even the brightest of students. Falling behind results in increasingly poor efficiency on your part. There is only so much time you can devote to chemistry, so it is important that it be done in the proper way.

Class material and coverage will assume the student is on schedule. Being on schedule means having read the assigned material, performed or at least attempted the assigned problems, and reviewed notes from the previous lecture. You may also consider copying your notes as soon after the lecture as possible. This allows you to interpret illegible portions of your notes and fill in sketchy details while they are fresh in your mind. Also collect any questions that may arise during note copying and ask them in the next class. If something is unclear to you, chances are it was unclear for many in the class. Also feel free to ask questions or point out errors made during the lecture (yes, rest assured we will slip up from time to time!). It is important that you build a solid foundation during this semester, and asking simple questions clarifying the material or correcting misconceptions is an essential part of laying that foundation. We also encourage you to form small study groups that regularly meet to discuss concepts or problems. Consider working with your class group! Try teaching your friends material you feel comfortable with — this is an incredibly effective method of learning for both of you!

Take good notes at every class, but do not sacrifice **listening closely and thinking** in an attempt to write down every utterance and note. It is often useful to listen for a period of time, then summarize what you heard in a sentence or two. Remember, all material covered in class, reading assignments, homework, and labs is fair game for exams.

As a final note about classes, we will not spend large amounts of time covering material that should be easily understood upon reading by every class member. Thus, topics like definitions and historical information will be covered rapidly. We will discuss the theory and application of the material, and work problems as time permits.

Help

The instructors are available during posted office hours or by appointment on a first come first served basis for help with conceptual, homework, or other problems. Additionally, we will conduct a help session before each hour exam. Do not become overly dependent on these sessions to learn how to work homework problems or to understand important concepts—it will be far too late for that! The help sessions are intended to clear up minor difficulties, and to present a review and integration of material rather than overcome a major lack of understanding.

Help will also be available on a regular basis from other St. Thomas students. Tutorial sessions staffed by members of the Chemistry Club or other upper-class chemistry students will be held from 6:00-9:00 pm Sunday, Monday, Tuesday, and Thursday evenings in 479 OWS. On occasion these students are available for individual tutoring; see your instructor to inquire about such an arrangement.

Finally, and most importantly, do not hesitate to ask for help from your classmates and the faculty. We can be of no service to you without knowing that you are having trouble. Please take advantage of any or all of the resources available to you.

Examinations

Exams will be based primarily on class coverage, though module and reference readings, homework problems, and laboratory work will also be covered. Exam questions may be problems which involve numerical or chemical work, short essay, true/false, multiple choice, or fill-in-the-blank. In general, make-up exams will not be given. If a student is to miss an exam for a legitimate reason, the student must make arrangements for a make-up exam **before** the exam date. Falling behind in your work and being unprepared for an exam is not sufficient grounds for delaying an exam, and usually only compounds the student's scheduling problems. Furthermore, special treatment for one or two students is decidedly unfair to the rest of the class. Keep current and work daily on your chemistry and you will succeed.

Exams will be given in the same room in which class is held. Exam materials may be passed out before the period begins, and the exam will end with the end of the period. Please be prepared to arrive early for exams. The dates of the exams are listed below, and each module schedule will remind you of the next exam date. **Mark these dates on your calendar. Make-up examinations will not be given.**

1. Monday October 5, 1998

2. Wednesday October 28, 1998

3. Monday November 23, 1998.

The night before an exam should be spent in a modest review of the module material. Note that the night before an exam is far too late to begin working problems from the text. To the contrary, this time should be spent re-working old problems, or better yet, trying to work new problems. Problems in Chang not assigned as homework, as well as the "Additional Problems" make excellent "self-test" problems.

We do not recommend studying the day of an exam, and absolutely do not advise all night cramming. These practices lead to a sense of desperation and often prevent one from thinking in the clear manner necessary for success.

Final Exam

The final exam will be conducted on the date and time indicated below. The final exam must be taken with your class section on the date indicated. **NO EXCEPTIONS**. The exam will be cumulative.

Section 01:	Tuesday December 15, 1998; 10:30 am-12:30 pm
Section 02	Wednesday December 16, 1998; 10:30 am-12:30 pm
Section 03	Tuesday December 15, 1998; 8:00 am-10:00 am

Grading

The course grade will be based on the following point distribution:

3 exams, 100 points each		300
Daily work and/or quizzes		200
Laboratory		170
Laboratory Homework	60	
Module Projects	120	
Final Exam (cumulative)	150	
TOTAL		1,000 points

Points accumulated during the semester will be totaled to generate overall grades. The distribution of points and corresponding grades are typically*:

88% and higher:	A's
78-87%:	B's
65-77%:	C's

*Each Chem 111 section will be graded separately, and the grades for each section of may vary somewhat from this distribution.

Students intending to register for CHEM 112 are required to obtain a grade of C- or higher.

Withdrawal From the Course

Unfortunately, it is inevitable that some people will need to withdraw from this course. Dropping a course is a serious decision, and the student should first confer with the instructor to discuss the situation and possible alternatives. Withdrawal from this course is not complete unless the student has checked out of the lab with stockroom personnel (485 OWS). One does not withdraw merely by not attending class. If you plan on withdrawing, inform both the lecture and laboratory instructors of your decision.

---

[1] If you're looking for more about modules in chemistry and how to use them, we recommend that you consult the articles above and the following web sites: http://chemlinks.beloit.edu/ and http://mc2.cchem.berkeley.edu/

[2] Stoichiometry: The art or process of calculating the atomic proportions, combining weights, and other numerical relations of chemical elements and their compounds. Webster's Revised Unabridged Dictionary, © 1996, 1998 MICRA, Inc.

[3] Periodicity: The repetition of similar properties in chemical elements, as indicated by their positioning in the periodic table. Source: The American Heritage® Dictionary of the English Language, Fourth Edition.

[4] For an example of a text taking this kind of approach, see Leo J. Malone's *Basic Concepts of Chemistry* [http://www.wiley.com/Corporate/Website/Objects/Products/0,9049,450778,00.html]

[5] For definitions of active learning, see http://trc.ucdavis.edu/trc/active/definiti.html. Bonwell and Eison explain how active learning leads to greater learning: "Use of these techniques in the classroom is vital because of their powerful impact upon students' learning. For example, several studies have shown that students prefer strategies promoting active learning to traditional lectures. Other research studies evaluating students' achievement have demonstrated that many strategies promoting active learning are comparable to lectures in promoting the mastery of content but superior to lectures in promoting the development of students' skills in thinking and writing. Further, some cognitive research has shown that a significant number of individuals have learning styles best served by pedagogical techniques other than lecturing. Therefore, a thoughtful and scholarly approach to skillful teaching requires that faculty become knowledgeable about the many ways strategies promoting active learning have been successfully used across the disciplines. Further, each faculty member should engage in self-reflection, exploring his or her personal willingness to experiment with alternative approaches to instruction." [http://www.ntlf.com/html/lib/bib/91-9dig.htm]

[6] For more on cooperative learning, see here: http://www.clcrc.com/

[7] For more on inquiry-based chemistry labs, see this: http://faculty.coloradomtn.edu/jeschofnig/inquiry.htm

[8] Physical chemistry is that branch of chemistry concerned with matters (no pun intended) of interest to both physicists and chemists. According to a web site at the University of Stuttgart, "the physico-chemist describes and investigates the physical phenomena arising from chemical processes. He [sic] tries to evaluate experimental data using the methods of experimental and theoretical physics, to reveal qualitative connections, to derive quantitative results on properties and states of matter as on chemical reactions. In addition, those results are applied to technical problems." <http://www-ipc.chemie.uni-stuttgart.de/world/pcstgt_e.html>

[9] See, for example, Tony Grasha's (1996) *Teaching with style: A practical guide to enhancing learning by understanding teaching and learning styles.*

[10] Project Kaleidoscope (PKAL) is an informal national alliance working to build strong learning environments for undergraduate students in mathematics, engineering and the various fields of science. Toward that end, PKAL sponsors

an annual series of Summer Institutes that provide opportunities for faculty, administrators and other stakeholders to: identify key questions and issues to be addressed in the process of strengthening students learning in these fields; share 'what works' - effective practices in creating, adapting, implementing and assessing new approaches; and share materials emerging from the work of leading agents of change. (http://www.pkal.org/)