Collaborative Teaching Across Freshman Information Technology and Chemistry Courses

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We incorporated chemistry into information technology (IT) programming assignments and IT problem solving into chemistry. At-risk students, performing well below control groups of their peers in both courses, achieved end-of-term chemistry exam results and IT final project results that were statistically indistinguishable (p varies) from control groups in either course.

Faculty at the United States Military Academy in West Point, New York, often look for potential collaborations between departments to provide the cadets (students) with a broader sense of how topics interrelate in their courses. Because our curriculum is very structured, with 30 core courses in a 40- to 43-course program, students are generally enrolled in the same courses as their peers, especially for the first two years (Kaufman 2004). This common course enrollment makes it possible to link courses and populate them with the same group of cadets. A link between the two-semester, freshman introductory chemistry course, General Chemistry (CH101/CH102), and the freshman information technology (IT) course, Introduction to Computing and Information Technology (IT105), was initiated to provide real-world IT assignments. There had been previous success linking the chemistry course to the freshman composition course (EN101) (Blackman, Gandolfo, and Kowalski 2005) through writing assignments on chemistry-related topics.

We decided that collaboration between our disciplines provided a way to help students form connections between ostensibly unrelated concepts. IT105 consists of approxi-
arily half information-technology topics and half problem solving using Java programming to implement solutions. The wealth of chemistry material using calculations provided numerous areas from which to create programming assignments in IT105. Moreover, the chemistry capstone lab assignment (described later in this paper) provided an application for the IT105 problem-solving approach and its associated tools. Due to the structure of both courses—40 lessons with set topics that must be taught to all freshmen without changing the lesson sequence—we decided that we would restrict our efforts to incorporating chemistry into IT programming assignments and IT problem-solving tools into chemistry. While Barrie (2005) and Brown (2001) had students use technology to do their calculations in chemistry, we focused our efforts on emphasizing problem-solving techniques in the two courses.

Selecting students
Seventeen students who met several criteria were selected. They were enrolled in both IT105 and CH102 (not the advanced versions of these courses) during their second-semester freshman year; they were not enrolled in a trial mathematics course (because other research already involved these students); and they were already scheduled at our respective class times, allowing us to have the same students in both classrooms. They were noticeably dualistic (Perry 1999) and stage-one (Grow 1991) learners. Dualistic learners are those that see teachers as authoritative and view knowledge in absolute terms. Stage one learners are those who are dependent upon teachers for their motivation. Only three students indicated they were considering a major in computer science, information technology, or chemistry.

Student anxiety
A major challenge was student perception of the two courses. Many students had struggled in chemistry the first semester and held negative perceptions of chemistry in general, which made them wary of having to explore chemistry concepts in IT. Additionally, the IT105 course usually makes students anxious because of their inexperience in that area and the course reputation. Many students feared that their perceived lack of ability in chemistry would impact their IT grade. On the first day of class, students were briefed on the collaboration in each course. Although the anticipation of facing chemistry in two classes caused many of them anxiety, most were glad to see the same students in both classrooms. We both encouraged discussion of their concerns and although their initial reaction was one of resignation, they developed a wait-and-see approach to the semester. We knew we would need to provide them frequent reassurance throughout the course.

Preparing the IT assignments
The IT course’s programming assignments require students to analyze a problem, design a solution, implement the solution in Java code, and then test the solution. The assignments emphasize selection (providing branching based on some criteria) and iteration (redoing a series of instructions while a given condition is true). They were based on topics covered and tested in CH102 prior to the commencement of the IT assignments. The problem descriptions provided all of the necessary chemistry concepts without requiring students to remember the chemistry as they analyzed the IT requirements of the assignments.

The topic chosen for the selection assignment was determining a solution’s chemical composition based on calculating its pH. The students were given a scenario where labels had fallen off three glass jars containing some white, powdery residue and colorless, aqueous solutions. Each of the labels indicated a compound—Ca(OH)₂, Pb(OH)₂, or Mg(OH)₂—that possibly corresponded to the substance in one of the jars. The solubility product constant, K_{sp}, of each of these compounds was provided and its associated pH calculated by students’ Java programs using stoichiometry. The calculated pH was then tested in the programs against a range of measured pH values, provided to simulate students physically measuring the pH of the unknown compounds, to determine which label belonged to which jar. Restrictions on entering the values for K_{sp} and on program logic were added to emphasize selection concepts. The flowchart logic for the solution is provided in Figure 1.

The iteration assignment explored the effect of soil pH levels on the color of hydrangea blossoms. The scenario involved planting hydrangea bushes in some percentage of a 100-square-foot garden containing soil of an initial pH value. The pH of the garden could be raised incrementally by adding lime to support pink blossoms or lowered incrementally by adding aluminum sulfate to support blue blossoms. The program calculated the number of bags of additive required based on the user inputs (soil pH, color choice, and percentage of garden). The logic for this assignment is provided in Figures 2 and 3. The box labeled “Input the values” represents logic to require users to enter correct values and to limit the scope of the logic of the program.
Developing these assignments was time intensive. The IT professor first had to learn the chemistry concepts. Writing the assignments involved supplying the relevant chemistry principles to students in layperson’s terms. (The IT professor used the assignment with all of her students, a few of whom were not currently enrolled in CH102.) The chemistry professor reviewed the IT assignments to verify that the chemistry complied with the fundamentals students learned and realistically reflected possible real-world situations. We worked together to select calculations of appropriate difficulty with realistic numerical values. The assignments underwent numerous iterations to meet the IT course guidelines and provide appropriate challenges.

Using IT in chemistry

Before this collaboration was established, the CH102 course director (at West Point a course director oversees the direction and teaching of an academic course; for freshman core courses, the course director generally oversees 30–60 sections of approximately 18 students taught by faculty who each teach two to four sections) decided to require cadets to draw a flowchart of the procedure for each lab. IT105 also requires cadets to create flowcharts for their programming assignments. Suggesting that cadets use the IT105 format to make their lab flowcharts was a natural bridge between the courses.

Typically the chemistry labs provide an introduction and procedure for students to follow, but the capstone lab requires students to develop their own procedure to accomplish one of four experiments in kinetics, thermodynamics, acid/base chemistry, or electrochemistry. Students work in pairs and the instructor’s role is limited to providing general guidance and ensuring students’ safety. The CH102 capstone lab was assigned shortly after IT105 introduced students to the problem-solving process they would use to develop their programming assignments. The four-step process, similar to those used in engineering curricula, consists of the following steps:

1. Understand the problem.
2. Design a solution.
3. Implement the solution.
4. Test the solution.

This process was well suited to helping students analyze their capstone task and develop their lab procedure; thus, this became another bridge from IT to CH102.

The largest application of IT to CH102 was the instrumentation and computers used in the lab. Each lab workstation was equipped with a computer and a LabWorks II module (LabWorks II is a set of sensor probes and analysis software used to collect and interpret data in a laboratory environment), which students used to collect temperature and conductivity data. They also used spectrophotometers and pH meters. Most of the lab experiments in CH102 used some kind of computer-controlled instrumentation.

In the end-of-semester survey, students involved thought that chemistry was well integrated into IT, but not vice versa—they did not consider the computers and
software used in the lab until the chemistry professor pointed them out. Apparently information technology is such a common aspect of everyday life that students took it for granted in the lab.

Academic counseling
The instructors met about every two weeks to discuss students’ progress in both courses. As recommended in the literature, students who were struggling were pulled aside to discuss their performance and study skills (Ambrose and Freeland 1997). As we learned more about each other’s classes, we used that knowledge to provide more specific guidance to students when we spoke to them.

Keeping each other informed about what was happening in the other course allowed us to get to know students better. Also, we could follow up on students’ discussions with the other professor to see if students had taken our advice and found it beneficial. In our classrooms and in individual conversations outside of class, each of us explicitly encouraged students to reach for higher achievement in the other course.

Student survey
In the end-of-course anonymous surveys completed before the final exam, students said their initial anxieties about the collaboration were not realized. Sixty-five percent indicated that they had felt scared, angry, or apprehensive when they were told that chemistry would be integrated into IT. Fifty-nine percent of students said that the experience did not match their expectations and seventy percent of those students specifically mentioned that the experience was not as bad as they anticipated. Seventy-one percent felt that taking two classes with the same classmates gave them and their teachers an opportunity to get to know them better as individuals. While some students enjoyed having two instructors looking out for them, one saw this as “creepy.” Students also felt that these two teachers were more understanding about the demands of their other courses. One student noted, “[The professors] were more willing to help in both courses when usually teachers seem like the course that they teach is the only course we take here.” These additional connections to peers and faculty have previously been reported in a similar context (Henscheid and Swing 2003).

Students also saw a disadvantage in having instructors who knew them well. In particular, they felt that they were letting two people down when they did poorly in one course. Interestingly, they did not mention that succeeding in one course would improve their standing in the eyes of two people.

Students’ reactions to the programming assignments were fairly positive. One student noted, “It was...a better use of programming exercises, i.e., more real world than some of the homework my classmates had to do from other instructors.” They thought their programming assignments were better written than those given to their friends and roommates taking the course with other IT instructors. We believe this reflects the time that we invested to make sure the insertion of chemistry did not handicap students as they completed the IT assignments. Students reported that the chemistry had not
hurt their grades in IT, but 71% also did not see that it helped their chemistry grades. (Note: This survey was taken before the chemistry final exam; see results discussion below.) They did see connections between the two courses, and 79% of students liked the experience of linked courses well enough that they would do it again. In similar multi-discipline collaborations, students involved reached the same conclusions (Blackman, Gandolfo, and Kowalski 2005; Froyd 2002).

**Results and conclusions**

By all indicators, the collaboration was successful. We offer the following insights and observations in support of this conclusion:

- Classes at West Point meet every other day and for these students, chemistry and IT met on alternating days. Students in these sections knew each other better than students in typical sections because they were in class together every day. They experienced better camaraderie and were more willing to assist one another than students in our other sections. Many of the pairs of lab partners from chemistry teamed up as project partners for their final projects in IT.

- Although students felt that IT did not help their chemistry grades, statistical analysis of their chemistry exams indicates otherwise. On the two exams given before the IT assignments that covered the same topics, their average scores were 21% and 14% below the combined performance of the chemistry professor’s other two sections (the control group). The mean scores (test vs. control) were shown to be significantly different at the 0.01 level (0.002 and 0.006) by the two-sample Fisher t-test on the mean (Glass and Hopkins 1984). These findings were consistent with results using Fisher exact median testing (Siegel 1956; Langsrud 2004). After completing the IT assignments, these students’ scores on their chemistry final exam were statistically indistinguishable from the control group for topics covered in the IT assignments (significance levels of 0.40 and 0.17 on relevant questions) as well as on all other topics on the exam (0.13 significance).

- Although not statistically significant, students also showed IT improvement. On the first three programming assignments, including selection and iteration, they averaged 3–6% lower than the IT instructor’s other section but their final programming project average was slightly above that of the other section. Since both sections completed the same assignments, this improvement reflects our mutual students’ greater increase in academic maturity.

- At the end of the semester, students thought we had integrated chemistry very well into IT, but that we had not brought much IT into chemistry. This reflects our initial intent to link the courses only by developing IT assignments based on chemistry scenarios. In IT, they were able to extract requirements for assignments heavily dependent on terminology from a discipline in which they had not excelled, and it did not impede their performance.

**Figure 3**

Logic for raising and lowering pH in the iteration assignment.
We opened their eyes to the ways in which the two disciplines can support each other.

- Students showed more progress in academic maturity over the semester in both courses than usually observed in other sections of students. The score of the first chemistry exam for students in this group correlated strongly (0.7) as a predictor for the score of the second exam, compared to a correlation coefficient of 0.3 for the control group (Glass and Hopkins 1984). The testing difference for these correlation coefficients is significant at the 0.05 level. However, their earlier poor performance was not a reliable indicator for their subsequent performance on the final exam on which they scored at or above the control group’s level. The data support our observations that the cadets grew as students during the semester. Our at-risk students now collectively performed as well as other students. The following year, their performance in the required two-semester physics courses was on par with the control group.

As faculty, we became sounding boards for each other, validating our own ideas for improving our respective courses and for advising students. One of the biggest lessons we learned was the necessity of planning well in advance if this type of collaboration is going to occur at all. This project was initiated only three weeks before our semester began, and we often felt we were building a house without blueprints, and living in the house while we were building it. Collaboration on this level is time consuming to do correctly. We compensated for the short lead time by spending large blocks of time together every week. We strongly recommend beginning the collaboration at least a semester in advance to provide the time necessary to sit in on each other’s classes, design interesting assignments, and identify where collaboration would be most valuable.

We also found that ensuring chemistry was not a barrier to success in the IT assignments meant providing chemistry explanations at the knowledge level of most students. We decided that students should be able to read and understand the chemistry principles in the IT assignment but that they would not necessarily remember every concept from their chemistry course. Because students in the IT professor’s other section were not necessarily enrolled in chemistry due to placing out of the course, this was even more important. We also needed to ensure that the activities in both courses were consistent with each course’s goals and objectives.

We would be interested in collaborating again, provided that we could arrange for more time to plan in advance. We did not intentionally select at-risk students but these results demonstrate how collaboration particularly benefited this population. Students’ achievements exceeded both professor and cadet expectations. As one student noted about his IT performance, “Even though two of the projects featured chemistry, I knew what I was doing. Though intimidating at first it turned out very good because I knew the chemistry…and could just focus on the coding.”

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