ACM-Teagle Collegium on Student Learning
Final Conference
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1. **Summary**. In a paragraph or two, what was the main teaching/research question of your project?

Can teaching metacognition strategies/behaviors mitigate the regression of student performance and attitudes in an introductory general chemistry course?

Analysis of historical grade data for my traditional courses shows a 1/2 to 1 letter grade decline in performance between the first and second semester general chemistry courses. This decline is particularly problematic for weaker students who often receive semester grades below C-, and develop a commensurate dislike for chemistry. My research question was formulated out of a desire to find effective teaching methods that can help these "at risk" students. My results suggest that a large portion of the barrier to success for these students is a lack of metacognitive skills. Rarely are these skills explicitly taught in a traditional chemistry course.

The Colorado Learning Attitudes about Science Survey tools have been validated and shown to be reliable. National CLASS data suggest a distressing regression in attitudes towards chemistry over a two-semester course sequence. Regression is defined as attitudes that align more closely with novice learners than expert learners. Using this assessment tool, I attempted to measure the efficacy of a studio lecture/lab environment and the explicit teaching of metacognition skills on the students' attitudes toward introductory chemistry.

2. **Context**. Briefly describe the teaching environment in which you investigated your question (level of course, number of students, course goals, time frame, etc.).

The teaching environment consisted of 12-15 introductory chemistry students learning in a studio environment. The pedagogy comprised POGIL (Process-oriented, guided inquiry) methods with specific attention to developing metacognitive skills. Students were able to self-select between the studio course or a traditional lecture-based course. Rather than the traditional three 1-hr lecture periods and one 3-hr lab period per week, six contact hours were redistributed as three 2-hr periods. Daily class activities alternated between group problem solving sessions and lab experiments. Daily homework assignments required problem solving and reflection skills.

3. **Teaching Practice**. How did you use your teaching question to inform your teaching practice? What were the main metacognitive strategies and interventions that informed your practice? How did your project change over the course of the Teagle Collegium?

Attention to specific aspects of metacognition were incorporated into almost every assignment. For example, an assignment opens with a list of learning objectives or a statement of the purpose of the work. Students work on their own to solve problems, take a position, or justify an experimental observation. At the next class meeting, they share and revise their responses with annotations indicating how their thinking changed as a result of the discussion. Upon completion of the assignment, students are asked a reflection question phrased to encourage them to assess their progress as related to to the objectives. In the reflection, they are encouraged to articulate connections between concepts and equations, or describe personal experiences related to the concepts covered in the assignment. In essence this is a work, share, revise, reflect sequence.

Other class assignments enhance the self-regulatory practices of students include reading reflections, knowledge surveys, and a course portfolio. This is the first time I have used a comprehensive learning portfolio. The portfolio serves two purposes: 1) Help students organize course content and capture artifacts that demonstrate their learning gains; 2) provide me and other experts examples of student work over a semester. The portfolios will be retained over time and will hopefully inform future decisions related to teaching practice and efficacy. Laboratory experiments were much more student-driven that in a traditional lecture-laboratory course. Students were given a prompt that required laboratory measurements to develop an acceptable response. With guidance, they were tasked with proposing, performing, and analyzing an experiment of their own design. Many students commented on the pleasures and frustrations of doing a "research-based" experiment rather than a cook-book experiment as in other lab courses. Again, frequent opportunities for self-assessment and regulation presented themselves demonstrating to students that metacognitive skills are not relegated to "book work" only.

4. **Conclusions and Evidence**. What conclusions have you reached about your main question? What assignments or performances provide evidence of changes in student learning or understanding in response to your practices? Please offer some description of your evidence and how you collected it.

The initial intent of my research was to seek (and hopefully explain) differences in student attitudes toward chemistry that may have been related to the studio learning environment. Unfortunately, the number of students taking both semesters of the studio course was very small, precluding meaningful comparisons. When this complication became apparent at the beginning of the second term, I looked at records of the incoming group of students and noticed a troubling trend in the academic profiles. Most of these students had (at best) mediocre grades in chemistry after one semester of traditional instruction. Reviewing the performance of students receiving a "C" in General Chemistry I, I noted a 1/2 to 1 letter grade decline in General Chemistry II. Based on past records, I would have expected several students (~25% of the class) to receive a "D" or "F" in General Chemistry II. Consequently, I altered my research plan to examine whether teaching metacognitive skills could help these "at risk" students maintain passing grades in General Chemistry II.

At the end of the term, the lowest grade given was a "C-". To verify consistency in performance expectations between the studio and traditional sections, I gave the same final exam as instructors of the traditional sections (Am. Chem. Soc. Standardized Exam). The class averages for both approaches were within a standard deviation of each other and well above national norms (65th percentile). Consequently, there seems to be evidence that the studio approach can help "at risk" students maintain better performance levels and does not hinder their mastery of chemistry content.

Despite the change in research question, I have continued to administer the CLASS, hoping to learn about changes in attitudes of *all* chemistry students irrespective of learning environment. Analysis of the survey results suggests that the Coe Chemistry program suffers slips in student attitudes similar to those of other institutions. As described below, these results have motivated discussions within the department about how to improve this situation.

5. **Implications**. How can this information inform future teaching practices (both yours and others')? How did collaboration with colleagues affect your project and practices?

The results of this work were presented on my campus to interested faculty. Though I won't claim this presentation was the cause, several faculty approached me for ideas and support in revising their courses to be more student-centered. They recognized that an emphasis on metacognition is an important component of success in these revisions and are incorporating it into their courses.

The work in this project has proved to be of interest to all members of the chemistry department because it helps us gather meaningful assessment data which can be used to evaluate our program. Although the CLASS tool was not used as originally intended, the results have been very useful in helping us identify regressions in student attitudes as they matriculate through the general chemistry sequence. Analysis of the CLASS shows how important metacognition is to improving students' attitudes toward chemistry, and thus has motivated a discussion within the department as to how we might enhance student learning in general chemistry. There is also interest on the part of one department member to include more student-centered activities in his course.

6. **Looking ahead.** What future modifications in your course, assignments, or approaches along the lines of this project could be made to further improve student learning? Where do you go from here with this project?

I am continually refining current assignments and introducing new ones with an overarching question: How does this assignment help students develop their knowledge of both content and thinking? Prior to this project I had a vague implicit understanding of how to evaluate assignments for these qualities, but now I do this explicitly. This has helped my understanding of the learning process and that of my students. Indeed, my assignment design process has been, in many ways, reversed. I have seen evidence supporting the merits of process-based rather than content-based assignments. A better understanding of metacognition is crucial to the design, implementation, and refinement of these assignments.

I am also exploring ways to share my findings with the academic community. I have collaborated with a physical chemist from a neighboring college about comprehensive redesign of the p-chem sequence to reflect the things I've learned in this project.

Additionally, I was given the privilege of helping design an integrated laboratory/classroom facility which will be a component of our upcoming building renovation. Having a physical space conducive to the pedagogy described in this document will enhance my (and others) efficacy in helping student learning.

More of my faculty colleagues are asking questions about the studio approach and considering how certain aspects of it might be incorporate in their instruction methods. The interactive nature of the studio is important, but logistically difficult to implement. Thus, I emphasize the importance of metacognition to all pedagogies and how these ideas lead to measurable improvements to student learning.

Lastly, I have new appreciation for the need to try to *measure* improvements in student learning. I have always believed in the necessity of data to confirm or refute anecdotal suppositions in teaching (just as in science). The task is daunting, but I was encouraged by many people involved in the project to plow ahead. A good plan is needed to answer any question about teaching and many useful ideas and strategies were communicated to me through this group. I hope to share the wealth with others...

7. **Bibliography.** What were the key sources that informed your project and that might be useful to fellow teachers and researchers?

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