Undergraduate Chemistry Research at Mesa Community College

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I believe that after taking two or three semesters of chemistry, students tend to have a fair understanding of the basic "nuts and bolts" of the subject. At this point they can be offered the opportunity to do some problem-solving requiring a certain amount of research or broader investigation. Doing research projects at this point has the potential to encourage students to engage in constructive hard work and to inculcate an interest for both the subject of the particular study and the overall process of scientific thinking—the latter being one of the expectations of a science education.

Further, students who are "out of the box thinkers" or "creative thinkers" many times feel stifled in the highly structured environment of "time-bound test taking." Research projects may provide such students with an avenue to express themselves scientifically in a more creative way. This may lead to their retention in class and increase their motivation to complete the semester and subsequently the degree program.

These two realizations have inspired me to offer undergraduate research options to students. Their excitement and further improvement in grades continue to motivate me. I have tried and tested two different pedagogical methods for such projects.

Approach I. Introducing Research in a General Chemistry Class

My first approach was to offer an "Undergraduate Research (UGR) Assignment" option in my syllabus for General Chemistry II, the course generally taken by students after they complete the Fundamental and General Chemistry I courses. The students who were interested in choosing this option were provided with suggested topics relating to the course's curriculum and textbook, but the topics required delving deeper into the application of chemical concepts. The students had to complete the

course's required reading and attend lectures. Then I offered to mentor/facilitate their work on the research topic they chose, during office hours or at any other time available. The nine students participating were interested in three topics, but finally selected one by a random lottery.

The students solved the problem they were interested in by investigating various aspects of the issue and related parameters. This required visiting the library, consulting various books, doing web-based searches, and discussing issues with me as their facilitator or supervisor. They did critical thinking regarding many aspects of the problem and ultimately summarized their observations, findings, and answers to the chosen question in a paper. Students collected relevant data or information available to support their conclusions and cited this information using the American Chemical Society (ACS) reference style. The students submitted their respective papers to me for evaluation as a part of their grade.

In addition to this paper, they had the option to prepare a poster and submit it as a part of this assignment. The students were also given opportunity to present their posters at the college-wide service-learning/undergraduate research showcase. This was visited by faculty judges, other faculty, deans, and other students. The participating students got an opportunity to speak about what they had found out.

Students opting to do this Undergraduate Research project option were given guidance to facilitate their critical thinking to help them complete the assignment. They consulted me during office hours and/or other available time. I gave them the opportunity to skip the semester test on the textbook chapter on which their assignment was based. Instead of taking the structured test, they instead focused on showing their familiarity with the material by completing the assigned investigation.

Approach II. Offering a Special Project Section

With this option, students enrolled for three credit hours in a separate special-projects section that allowed them to do laboratory-based undergraduate research projects. Just one or two students could be enrolled per semester. The students did the work during the semester and presented it at a faculty forum. They generated original data and discussed their results. Students got so involved with their research. They ended up extending their lab experience by enrolling for consecutive semesters in the special-projects class and furthered their projects in subsequent semesters.

Whereas the first pedagogical approach was more useful for B-level students to achieve better understanding of the course material and was a powerful method for introducing students earning B- or C grades to an alternative learning method, the second approach clearly appealed to the

out-of-the box and adventurous thinkers, as well as to high achievers (usually A-students) who wanted a new learning experience.

In undertaking the pedagogical experiments, my primary hopes and expectations were for:

- enhanced student interest in learning chemistry,
- a benefit for "out of the box" thinkers,
- an innovative, enjoyable and worthwhile undergraduate research experience for students,
- better student understanding of chemical concepts and improved grades in the class, and
- better student motivation to complete the semester and, subsequently, their degrees.

General Results

Among the nine students choosing Approach I—the research option within the General Chemistry II course—four of the nine typically scored B's in previous coursework. Their intention was to gain more understanding of the subject, even though they generally had low levels of confidence and low self-images as students.

This approach allowed the students two to three months of the semester to study and digest the material and do the project, versus spending 75 minutes taking a test in class on the same material. The extended time took the pressure off and gave participants motivation to study that boosted their confidence. During this time, I was available to help students understand the materials. Students also told me that it helped that I offered help to organize their research and assist them in outlining their poster.

Throughout the project, I met with students and asked detail- oriented questions regarding the content of their projects to help them think and increase their knowledge base—essentially trying to push them to A-grade study habits. Also, empathetic questions throughout the semester about how they were "feeling" gave them a chance to voice their concerns.

I found that B-students achieved better understanding of their already adequate subject knowledge, and they had the experience of learning presentation skills and thus boosting their overall confidence. C-students who were struggling with time constraints in their schedules and who had difficulties taking tests got a ray of hope through this alternative study method. They also got the experience of presenting their project work. And A-students who were "out of the box" thinkers got a reprieve from traditional test-taking to study and perform differently. They also got presentation experience.

Approach I. Some Specific Chemistry Projects and Results

Some students improved their performance and grades through participation in the research option. I will discuss seven of the nine. For example:

- One student reviewed the process of creating ammonia from hydrogen and nitrogen. She demonstrated very good understanding of the concept of chemical equilibrium, progressed very well in tests on information in other chapters of the textbook, and passed the semester by bettering her grade to an A.
- Another female student studied different types of chemical reactions in wastewater treatment in the local city, learning which ones cleansed the water so that it could be released back into the environment. Studying the material in the course's textbook on chemical reactions in this manner helped deepen her understanding. She earned an A on the final exam.
- One male student who was having difficulty on chemistry tests decided to study the textbook material on chemical kinetics by investigating formation of photochemical smog. By this applied work on the kinetics, he learned where we as a society can prevent this chain of reactions and have healthier air to breath. He also bettered his grades to an A by getting interested in the subject.

Three of the students were typically scoring C's when they chose the research option as an alternative to taking conventional tests on particular material. They did not have clear study habits, were dependent on being spoon-fed material, and had low academic standards for themselves. Requiring them to make and present posters based on their research facilitated independent thinking and promoted a clearer focus on the content of the material they were studying and investigating. The presentation requirement forced them to actively engage in their independent study. Since the poster presentation was an alternative to test taking, the students were compelled to give their maximum efforts. They realized that they got a better understanding of the subject this way and were more motivated to learn.

The research approach definitely helped one student who was a very hard-working student who kept missing a B by a small margin. She was beginning to feel dejected and was thinking of dropping the class. When offered this research option, she took up the study of acids and bases using by real-life examples. Her focus on and interest in the subject suddenly began to grow. She not only produced a very succinct paper and poster but also hiked her grades in the later part of the semester and passed with a high B.

Two of the students who took the research option were typically scoring A's to begin with, but they wanted to obtain extra experience. They demonstrated hyper enthusiasm for the project initially, which led to haphazard study and over-confidence, which led to a lack of details and quality. Thus, as they were preparing their final presentation, I told them I expected them to outline various paragraphs, complete with subtitles, before writing their detailed paper, and I asked them to address detailed questions that required them to do extensive reading and research. Throughout the process, I was there in person and via emails to answer queries when they had any.

Ultimately, this research experience gave students a feel for independent yet logical scientific thinking and investigative skills. They also experienced a presentation experience akin to a thesis defense. One student who studied chemical compounds in saliva and tooth decay ultimately made a flawless presentation and planned to attend dental school. She earned high A's in all her chemistry classes at Mesa.

Approach II Projects and Results.

In Approach II, four students carried out special-section research projects. The students were already earning GPA's of 3.8 to 4.0; two aspired to get their bachelor's degrees in chemistry and the others were planning to go to engineering and medical school. With these students, I found I needed to monitor them constantly to insure that they maintained high standards in their work and achieved their maximum potential, making sure that they had the requisite equipment available and that experiments were proceeding on a logical track. Fortunately, universities and a local laboratory willingly helped out, giving their equipment and lab support for students' projects.

Before preparing their final presentation, these students were asked to write a detailed paper about their projects. They were expected to outline various paragraphs with subtitles and were asked to address detailed questions that required them to do extensive reading and research. They were also required to do a mock presentation of their project, accompanied by possible queries.

This pedagogical approach produced some interesting projects. One student did a lab-based project investigating the presence of the heavy metal cadmium in soils. Investigation included the methodology of obtaining and handling samples, the chemical process of determining cadmium levels, and a discussion of the results. This student ultimately did a graduate degree in engineering. Another student studied whether wheat grass could be used to remove cadmium from polluted soil using the process of phytoextraction, since it has a much smaller ecological impact and is cheaper than current

clean-up methods. Yet another student studied textile dye waste generated on campus. In this laboratory-based study, dye wastewater was added in differing concentrations to soil samples containing two types of plants, which were grown in a controlled greenhouse atmosphere. The results led to the conclusion that this approach could possibly provide a "green" method of dye-waste disposal that could also beautify the landscape.

Conclusion

I am excited that all my initial hopes and aspirations for the two different pedagogical approaches have come true for most of the students opting to participate in some kind of undergraduate research. This gives me a certain degree of confidence that research can offer students a potent avenue to express themselves scientifically in a more creative way. This may instill in them a new-found liking for the discipline and motivate them to pursue and complete the semester and the degree program.

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