

Learners as Teachers: Student and Community Outcomes of Service-learning in an Undergraduate Chemistry Course

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Abstract:

In this article, the motivation for a service learning tutoring project involving college-level chemistry students and area high school students is described. It is followed from its conception through various refinements over the course of several semesters of implementation. Course content assessment is described and discussed. Attitudinal survey data is also discussed along with evidence from student reflections. Community partner impact is presented. Personal efficacy, social and civic responsibility, and diversity attitudes as a result of the project are also discussed.

Key Words:

scholarship of teaching and learning, service-learning, chemistry education.

Introduction

As an instructor of Chemistry, part of my teaching load includes teaching Principles of General Chemistry, a one-semester chemistry course required for admission to the nursing program. The Principles of General Chemistry (PGC) class is required for nursing students, and is the only chemistry class these students are required to take. Typically, the students enrolled in this course have a varied background in math and often no prior experience with chemistry. Often this is accompanied by a somewhat negative or apprehensive attitude about taking the course. Some of them also seem to not see the relevancy of these subjects to their careers. For the nursing degree at Rockhurst, the one math class that is required is Pre-Calculus. The PGC class is offered in the fall semester, and most of its students are first-time college freshmen. These students not only struggle with the notion that chemistry and math are difficult and irrelevant; but they are also adjusting to the major life changes that first entering college brings.

Chemistry is a discipline that requires practice to gain familiarity and facility. First time freshmen often lack the study skills necessary to be successful. This, coupled with the anxiety and lack of motivation toward the subject, often spells disaster for these students. Without practice, however, it is difficult to find success in the class. Frustration often causes the students to disconnect completely from the class and the downward spiral begins. I had long been disappointed with my ability to improve learning and success in this particular class. I searched for a different approach to provide an avenue for practicing chemistry that might enhance engagement and success in the class. Despite the challenges of engaging students in a content heavy course, others have found some success using cooperative learning methods (Coppola and Lawton, 1995; Gosser and Roth, 1998) and problem-based learning (Mills, Sweeney, Marino, and Clarkson, 2000; Harvey, 2002). Jacobs (2000) described how his more active chemistry course helped develop content knowledge in addition to communication skills and confidence - tools necessary for success in science.

Tutoring Project Phase 1 with Principles of General Chemistry Nursing Students

In an attempt to increase the students' investment in the course while also providing them with an opportunity to practice chemistry, I decided to have the students tutor chemistry to nearby high school students. My main motivation was to place the students in a situation where they had to explain chemistry to someone else. This required them, of course, to understand the material themselves or to see where the gaps in their understanding might be and to articulate that understanding to other students. I wanted them to also feel that they were responsible for other students' learning – so that even if they were not interested in learning the chemistry for their own benefit, they might be invested in the tutoring process to help the students being tutored (with a side benefit of actually internalizing the material more fully). Tutoring has been shown to enhance the student's understanding because the learning experience is interactive (Chi, Siler, Jeong, Yamauchi & Hausmann, 2001). There is also evidence to suggest that time spent studying with another person is more productive than time spent studying alone (Faichikov, 2001). Tutoring places the students in a different situation to have to explain, in their own words, a chemical principle or concept. This is not always the case in the classroom, but it can be helpful in solidifying a concept. I also remembered from my own experiences tutoring how effective it was in reinforcing subject material. While all of these things are true this is also a classic example of service-learning. Service-learning has been shown to improve student understanding and application of content material (Eyler & Giles, 1999; Strage, 2000).

So, my hope was to try something different with this group of students and to offer an experiential learning opportunity to this class. I wanted feedback from the students who were tutoring to track their progress in terms of the chemistry that they were working on and also personally. I actually did not realize that this type of activity roughly fell in the category of service learning. It was simply an idea for improving learning in a class where many previous attempts had failed. Since this new approach would require extensive planning and coordinating, I wanted to be sure that it would have the beneficial effects that I anticipated – that it was worth the effort on everyone's part. To

that end, I tracked the progress of the tutors compared to the non-tutors in the same class and compared to non-tutoring classes from years past.

The Partnership

Rockhurst University's (RU) location in Kansas City places it geographically within the Kansas City Missouri public school system. This is a system that currently has only provisional accreditation from the state with schools failing to make acceptable progress on the Missouri Aptitude test. The specific partner selected was University Academy, a charter school within the KCMO district, located approximately two miles from RU's campus. UA is a high school designed to prepare students in a low socio-economic status for college. At UA, students are required to take a course until they pass it. In the General Chemistry course that the RU students tutored, several of the UA students had already taken chemistry once and some more than twice. Retaking a course several times without an improvement in the grade can lead to frustration and apathy. Many of the UA students went to tutoring with the idea that they would never understand the information, a problem that the RU students had to deal with both within themselves and within the UA students while tutoring.

The demographics of UA are mixed sex, and African-American (99%) with 64-78% qualifying for the federal lunch program depending on the year. The demographics for the class at Rockhurst University (RU) are primarily female, middle-class to upper middle-class, first-time college, and Caucasian.

The Project

Those that participated in the tutoring spent 30-45 minutes tutoring once a week for a minimum of ten weeks. The students were required to respond to a survey every week that they tutored, and then a final survey was given after the semester was completed. Written reflections as well as statistical data were used to analyze whether or not tutoring was beneficial. The UA students were learning the same information that the RU students were learning, which helped to reinforce the information in the minds of the RU students. Although, my initial goal was to make tutoring mandatory of all students in the class; my community partner expressed concern about students being forced to tutor if they did not want to and the effect it could have on the relationship between my students and the high school students. So, while strongly encouraged, students participated in the program on a voluntary basis and there were homework points available for emailing me a reflection each time they tutored.

Impact on Exam Scores

Class performance of UA tutors was compared with non-tutors in order to analyze the benefits of tutoring. A pre-test consisting mainly of math was given at the beginning of the semester to serve as a control. Another survey was given prior to tutoring in order to gather the chemistry background of the students interested in participating in the tutoring. In the 2005 PGC course, 31 out of 45 students participated in UA tutoring.

Five exams were given. Table 1 contains the average exam scores.

Table 1: average exam scores

Student	Exam 1	Exam 2	Exam 3	Exam 4	Exam 5
Tutor	81.83%	77.19%	63.61%	69.81%	78.07%
Non-Tutor	75.76%	63.38%	51.47%	59.67%	68.23%

Five questions from each exam were chosen ranging from easy to difficult. The questions were chosen for content (looking at specific concepts) and were matched in wording as closely as possible between the two years. For example, a level one question encompasses only one concept and this concept is typically taught in high school chemistry classes and other science classes.

A level five question requires several steps to complete. First, the student must recognize the connection between density and volume. Then the student must set up and solve an appropriate equation. An understanding of the concept covered in the level one question is also required.

Correlating questions were chosen from the 2004 exams, as well, to add to the non-tutor pool. Each question was analyzed statistically to determine if tutoring was beneficial. In exam two, tutoring was shown to be significant only in question five, the most difficult. In a two-tailed t-test, the significance was 0.042. Exam three showed no significance between tutoring and any of the questions. Exams one, four, and five could not be analyzed with both years because the data for these exams was not available for 2004. Exams one and four were analyzed within 2005 using the five questions, but only question two in exam four showed significance in a two-tailed t-test (0.038).

Table 2: Exam Analysis

Exam Analyzed	Question 1	Question 2	Question 3	Question 4	Question 5
1, 2005	*	*	*	*	*
2, 2004,2005	*	*	*	*	0.042
3, 2004,2005	*	*	*	*	*
4, 2005	*	0.038	*	*	*

*: Not significant

Impact on attitudes of those who participated in the tutoring project:

Students were given a pre-tutoring survey involving questions about their attitudes toward chemistry. In the years that I had taught this course, I was always struck by the negative or at least worried attitude that many students entering the course seemed to have. I decided to try to capture this in a survey. The survey had the following 8 questions:

- I enjoy the study of chemistry.
- Chemistry is difficult for me to understand.
- Difficulty with understanding chemistry is related to difficulty with doing math.
- Chemistry is relevant to my future career.
- Chemistry is applicable to my world or daily life.
- I am less comfortable in a chemistry class than in other science classes.
- I feel intimidated when working in a group setting.
- It is easier for me to understand science when I am engaged in active discussion and hands-on activities.

In this survey, the majority stated that they “strongly agreed” that chemistry was relevant to their future career, but the majority also “slightly agreed” that chemistry was difficult for them to understand. The majority also said that they “slightly agreed” that it is easier for them to understand science with active discussion and hands-on activities.

The math pre-test showed an average score of 80% with scores ranging from 38% to 100% on 14 questions. The questions were similar to the type of math functionality needed in a basic chemistry course. There were unit conversions, simple algebra, and multi-step algebraic problems.

Those RU students that participated in tutoring were given a post-tutoring survey as well with questions regarding their feelings on the effects of tutoring and the experience as a whole. An overwhelming majority either “agreed” (72%) or “strongly agreed” (28%) that they enjoyed tutoring and that tutoring improved their understanding of the subject “agreed” (56%), “strongly agreed” (40%). The majority also either “disagreed” (64%) or “strongly disagreed” (12%) to the statement, “I feel I would have learned more from this course if more time was spent in the classroom instead of doing community work.” Aside from the chemistry, students also felt that the tutoring enhanced their communication skills. The majority said that they either “agreed” (68%) or “strongly agreed” (24%) that the work they performed in the community enhanced their ability to communicate in a “real world” setting.

After each tutoring session, students were asked to answer reflection questions regarding their experience that week. These questions were meant to prompt the student to think about the meaning behind the work that he/she was doing. Bringle and Hatcher (1996) include reflection in their definition of service-learning, explaining that reflection is needed “...to gain further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.” The answers to these questions not only allowed the students to recognize the meaning behind the work they were performing, but also served as feedback for the teacher on the benefits the students were receiving and ways in which the students felt the tutoring would be more effective.

Reflection Questions Used

1. Describe an incident from the day and analyze it in terms of your own reaction or the reactions of others.
2. Indicate what you could do differently if faced with a situation similar to the one described in Question 1.

3. Describe a specific problem or success in as much detail as possible that was encountered when explaining a chemistry or math-related problem to the students at University Academy.
4. Please share any additional comments.

Samples of Answers to the Reflection Questions

There were many themes that emerged from the answers to the reflection questions. These questions were available each week on a WebCT site and entered directly into the site. They could then be accessed by me. The questions did not lead to a lot of free response, but it was possible to gain some insight into how the tutoring was going and what the students thought about it. Two primary themes emerged: strengthening chemistry skills and development of human beings. Some examples of student responses are listed below.

Strengthening chemistry skills:

- Together, Lisa and I were trying to explain to a few of the girls how to tell how many protons and neutrons were in an atom. Since we ourselves were still learning about it we had to ask Dr. Lee to make sure how to tell. Asking for help and then teaching it helped to reinforce the idea into my head and hopefully helped me teach it to the students better.
- I really enjoyed it and it helped me refresh my memory of the topics covered before my test today.
- In helping them I am not only helping them have a better understanding of chemistry I am also forcing myself to put what I learn into action.
- I found that by helping the students it actually reinforced what I was saying into my own head and now I understand it better.
- I need to study my chemistry on my own so I can feel more confident when tutoring.
- There was one problem where neither Lauren nor (I) understood it, but we asked one of the other girls and their student and afterwards everyone understood the question better.
- In helping the student understand the questions it also helped me to better understand the material as well.
- The University Academy tutoring is helping me giving a weekly feedback where I lack in the last week's class.
- I really think that I am gaining a lot more knowledge of chemistry by tutoring every week.
- I think the tutoring is a great idea because besides giving us the opportunity to help kids succeed in school, it also helps us review our chemistry skills as well as learn new things that could help us later on in our own chemistry class.
- I like tutoring there...i feel like it gives me a better handle on the material

- Today was fun and I really enjoy being able to work with these students. Not only does it help them but it forces me to make sure I know what I'm talking about
- The students are getting pretty good, soon they won't need our help hahaha.
- It's still fun. I like how the same kid comes every week. It really does help me remember the info better as well.

Development as human beings:

- I genuinely enjoy doing this. At first, I was doing it for the credit, but I'm really glad these kids are benefiting from it.
- This type of tutoring will definitely help the students there and it will help building confidence in us too.
- I really enjoy tutoring and it has prompted me to begin tutoring at Children's Mercy Hospital.
- I really enjoyed tutoring today because I feel like I made a difference in that girl's life by giving her my attention and knowledge.

Impact on the Tutored Students

While much research documents the positive effects of service-learning, not as much research has examined the effects on community partners (National Service-Learning Clearinghouse and Campus Compact, 2010). The University Academy students who attended tutoring sessions scored, on average, 23% better on their exams (an increase from 36% to 59%). The students that passed the exams (with the exception of two) attended tutoring at least twice. Individual test scores of those that attended tutoring at least twice were consistently higher than those that did not attend tutoring. The final passing grades in the UA class were as follows: A=1, B=3, C=3, and D=17. The majority of the C and D grades and two of the B grades were received by students that attended tutoring at least twice.

An unanticipated benefit of the tutoring was an increase in the number of assignments turned in by the UA students who attended tutoring sessions with RU students. This no doubt helped them receive their passing grades. It seems plausible that the tutoring affected this phenomenon. The faculty liaison felt strongly that having individual attention for his students dramatically increased their engagement in class.

Tutoring Project Phase 2

The Principles of General Chemistry course is a one-semester course. In the following spring, the community partner contacted me wondering when tutors would be coming. In all of my planning for the tutoring project, I had not considered this important component – that I would not be providing tutors for the spring semester. So, I decided to immediately poll my current General Chemistry II students if they would consider acting as tutors for the remainder of the year at University Academy for a nominal number of extra credit points in the class. I decided upon 2 points per tutoring session which would encourage students to tutor multiple times, which would provide the University Academy students with a consistent stream of tutors. The new set of tutors

would still be required to reflect upon their tutoring experiences to receive credit. However, an important change was made in this reporting. Because I did not have the same WebCT system set up for this particular course, I asked the students to simply email me directly with their reflections each time.

This seemingly simple change, affected the future dynamic of my interaction with the tutors. The immediacy of emailing allowed me to enter into “dialog” with the tutors. It strengthened my relationship and knowledge of each of the students and very much enhanced my interactions with these students in and out of the classroom. In the previous semester, on WebCT, I would access the tutoring surveys once every couple of weeks because it involved a somewhat complicated download and export and then I would have dozens to hundreds of responses to read at once. With email, I could easily read and respond to the students. I could have them come by for a talk if there were any issues or concerns. It personalized the tutoring in an important way. In every semester since then, tutors have emailed their reflections to me directly. It helps me get to know the students which change their engagement in the classroom. This is particularly important with first or second-semester freshmen who are, at times, having difficulty adjusting to college or being on their own for the first time. Connecting to them regularly via email gives them some stability and security in the whole first-year experience.

The following year, after a relatively successful pilot experience with tutoring, I decided to embark on the tutoring project again. However, shortly before the semester began, my community partner let me know that he would no longer be teaching at University Academy and further, that University Academy would not be offering chemistry that year.

So, I was connected to another Charter High School in the KCMO district, Hogan Prep Academy. The chemistry instructor there was very interested in having tutors. However, Hogan Prep had recently received a grant to offer Advanced Placement (AP) Chemistry, offering a total of three tracks/levels of chemistry to their students. This caused me to change my focus from the Principles of General Chemistry students to the regular-track General Chemistry I/II sequence students. Since the AP Chemistry class was now a possibility for Rockhurst tutors to work with and the material in an AP class is essentially General Chemistry I/II, I did not think that the Principles of General Chemistry class was a good fit for tutoring. While tutoring does introduce some discomfort in students because it pushes them to sometimes explain things that they are not completely familiar with, I felt that the PGC class attempting to tutor students taking AP chemistry would not be a good fit leading to positive experiences for the PGC tutors. So, I completely changed the tutoring pool to the 2-semester General Chemistry I and II sequence taken by majors and pre-professional students. It had gone very well having the General Chemistry II students tutor the previous semester and I felt that this was going to be a good fit for Hogan Prep’s wide variety of needs.

After the UA experience of after-school tutoring, and given the flexibility of the college schedule, my partner at Hogan Prep and I agreed that having students tutor during class (as opposed to an after school program) could have some major benefits: the Hogan students would not be there optionally and it could allow for one-on-one tutoring for students needing extra help. One issue my Hogan partner indicated was that the wide range of abilities and backgrounds in one classroom usually meant spending

time to bring the students who were behind up to speed at the cost of the better-prepared students. With Rockhurst tutors, she could place the students needing help with tutors while moving at a better pace with the remainder of the class.

Impact on Attitudes

As the project shifted to the General Chemistry I and II students, a dramatic change in the reflections occurred. It is quite possibly because of the more intimate mode of reflecting on email as opposed to entering responses into a WebCT site. But, as soon as the reflection mode changed from WebCT to email, the detail, richness, and information from the reflections improved. Related to this, I also noticed an increase in class participation and confidence among tutors similar to that found by Quezada & Christopherson, 2005. It is hard to know whether this came from the tutors explaining the material and feeling more comfortable with it, or because the tutors had an inroad to me personally and had chatted with me on email about tutoring, so they felt more comfortable in class participating with me. Either way, there was an enhancement in the class discussions and participation among the students who tutored.

I also noticed many more results not related to chemistry coming through the emails. More of the students seemed to be considering issues of justice and civic responsibility after tutoring. These angles had not surfaced in any of the responses on the WebCT site. Several times each semester, tutors were stopping by to discuss something that bothered them about the situation of these students – usually related to the lack of preparation or poverty that the Hogan students experienced. For many of my students, they seemed to not have considered this deeply prior to tutoring. These are hallmarks of service-learning experiences (Eyler and Giles, 1999).

Strengthening chemistry skills:

We helped them walk through the Periodic Table and showed them the corresponding orbital levels for different elements. It was great review for me. Everything came back to me during the lecture, and I was able to help the students understand the concept.

Development as human beings:

- I went to tutor at Hogan Prep High School last Thursday, 9/17/09. We went at 9:30 and came back around 10:30. There were two periods we worked with. Both were reviewing for a paper they had to write detailing the heating curve, states of matter, and state changes, and how various properties of matter related to each other during each of these states. I primarily helped people with describing the relationships and how to generally structure the writing.

I was surprised at how far behind the Hogan students are in their learning compared to ourselves. At the same time, I was surprised and frustrated at how little I understood the material myself, having left it alone for so long. It was a wakeup, both in terms of my own ability and the abilities of others. When I brought my concerns to the teacher, she told me that it didn't matter if I didn't understand completely, and in fact it was beneficial. She told me that for them, to see that someone like myself, who has had everything easy academically, struggling with the same material as them, who have had a difficult educational

road, it is highly motivational for their performance. I was both saddened and inspired by these sentiments and I am eager to continue helping as much as I can.

- I love working with people more than anything. Making others believe in themselves is important to me. All of the students there have such great potential for everything in life, and they all want to make a difference. It's very inspiring.

Impact on Community Partner

Observed about Rockhurst students: From my community partner: "Overhearing them, they shared stories of growing up and life and that seemed to overcome a few more barriers set up by culture, economics and race. I watch your students over time. I see them come with preconceived ideas about black, inner city kids, and poverty and violence, and I see those conceptions change. I am not sure I could quantify anything but it seems that the Rockhurst tutors are somewhat afraid when they come, and as that fear goes away, and they get to know the students they work with better, they find there are a lot of similarities, but the differences were probably not even known before they started working here. I felt like several of yours not only confronted some of the racial issues, but could see them in light of their own white privilege that doesn't require them to deal with what they don't want to see. That is a big step."

Observed for Hogan Prep students: "The tutoring went very well for several reasons - since all the Juniors must take chemistry - not all are that well prepared for the subject. The tutors were great at working with those who had difficulties with things like formulas, electron configurations, using the periodic table and things like that. In addition - it was really great for the AP students to see that the college students were studying in the same areas they were and that college students ask questions when they are not sure of the answers. The level of the questions in class increased as the year progressed. It did work well to have the tutors come during class, because that way I knew there would be students there to work with and I could assign students who were behind or struggling to get individual help with the tutors."

Conclusion

Qualitative data from pre- and post- surveys indicate that tutoring offers a different way for students to work with chemistry that enriches their learning possibly by tying it to a more human or personal interaction. This interaction is also enhanced with me as their professor since they discuss their experiences with me directly. This access to and familiarity with me then affects their classroom behaviors and possibly their success in the class. Yet more work needs to be done in order to quantify the actual impact of tutoring on the learning of chemistry.

The benefits to the students as human beings and citizens in the world are also of interest. It is difficult to encounter a mission statement for any institute of higher learning that does not mention preparing students for their future, serving others, making the world a better place, etc. The interactions that these students have while tutoring may impact their attitudes, their career paths, and their approach to civic responsibility while also deepening their understanding of chemistry. Considerable research into the impact of service-learning supports these findings in the areas of leadership and civic

engagement (Moely, McFarland, Miron, Mercer, & Ilustre, 2002 and Delli Carpini and Keeter, 2000) as well as diversity attitudes (Boyle-Baise & Kilbane, 2000 and Green, 2001) and personal efficacy (Quezada & Christopherson, 2005). The American Association of Colleges and Universities (AAC&U, 2007) has presented the Essential Learning Outcomes as a part of their initiative to help prepare students for what they will face in the contemporary world. Knowledge of human culture, intellectual skills, and personal and social responsibility are the cornerstones of this work. Tutoring fits easily into all three categories.

Through my courses I hope to help students develop as scientists and also as human beings. While more work is needed, I have found these projects help me come closer to these goals in a way that would not happen in what would be considered a more traditional classroom setting. Though this approach to teaching Chemistry is more time intensive, the benefits to me and my students cannot be overstated. There is more of a sense of community in the classroom as a result of this work I have come to know my students more deeply and in a different way than I might have without the additional interaction from the reflection email discussions. Additionally, the tutoring project has made me more excited about getting into the classroom and has reinvigorated my teaching. I recommend this approach to anyone who is interested in interacting with students and delving somewhat into character development. The time spent on reflection emails is well worth it in terms of the gains in classroom conversation and participation. The time spent practicing chemistry is beneficial to any student, whether strong and well prepared or weak and lacking confidence.

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