Student-Generated Connections to Chemistry Content to Enhance Interest in Introductory Chemistry

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ABSTRACT

Research on motivation has shown that students perform better when they perceive utility-value in their course. Utility-value is a domain of motivation that is reflective of the perceived importance or usefulness of a task for accomplishing future goals. In this study, students in a community college introductory chemistry course were tasked with writing about how certain chemistry concepts were related to their future careers throughout the semester to potentially increase their perceived utility-value of the course. In comparison to a control group, these students had higher overall course grades, found chemistry more interesting, and the course material more useful. The impact on motivation seemed to be larger for underrepresented minority students when compared to white students.

INTRODUCTION

Contextualizing course content has been shown to have a positive impact on student interest and performance in science. Student interest and motivation increase when they are able to connect the often abstract science concepts to phenomena with which they are familiar (Kaschalk, 2002; King et al., 2008; Murphy et al., 2006, O'Connor & Hayden, 2008; Sristy, 2023). Their views of the relevance of chemistry also improve, as they can see how it relates to things they experience outside of the classroom. Students who are more motivated work harder in their courses and are more interested in course material, which correlates with them performing better. Their conceptual understanding of chemistry concepts and problem solving skills also improve when they are taught about chemistry in context (Barker & Millar, 1999; Barker & Millar, 2000; Belt et al., 2005; Glaser & Carson, 2005; Heller & Hollabaugh, 1992; Park & Lee, 2004).

While there are many benefits to teaching chemistry in context, one limitation is that typically the contexts are chosen by the instructors, not the students. There are obvious practical reasons for designing a course this way, but it risks connecting concepts to phenomena that students do not find relevant or interesting. Each student has their own interests and experiences that inform their perception of the world that is impossible to fully capture by pre-selecting contexts to focus a course around. A potential way to address this issue is for students to generate their own connections to course concepts to provide more personal relevance and further improve their motivation and course performance.

Motivation has many domains, one of which is utility-value (Eccles & Wigfield, 2002). This domain is the perceived importance or usefulness of a task for accomplishing future goals. Research has shown that when students perceive utility-value in their course, they develop more interest, work harder, and perform better (Harackiewicz & Hulleman,

2010). Perceived utility-value can be promoted by having students write about the relevance of course topics, which allows students to discover connections on their own. These self-identified connections are more meaningful than those provided by an instructor. Students who wrote about why concepts in an introductory biology course were personally relevant had higher overall course grades than those who just wrote an explanation of the concept (Harackiewicz et al, 2016). In addition, this intervention lowered the achievement gap for first-generation and underrepresented minority students. The achievement gap was reduced by 40% for underrepresented minority students in the treatment group and their final grades improved by 0.20 grade points (on a 4.0-point scale) compared to their peers in the control group. First-generation underrepresented minority students in the treatment group improved their final grades by 0.51 grade points, resulting in a 61% reduction in the achievement gap.

Utility-value interventions have also been shown to increase retention in science, technology, engineering, and mathematics (STEM) fields (Asher et al., 2023). Students in an introductory chemistry course at a large 4-year institution who wrote about why concepts in their course were personally relevant were 4% more likely overall to still be STEM majors 2.5 years later and the effect was greater for underrepresented minority students, who were 15% more likely to still be STEM majors. In addition, improvements in grades and interest have been seen in high school science (Hulleman & Harackiewicz, 2009), high school math (Gaspard et al., 2015), 4-year college psychology (Hulleman et al., 2010; Hulleman et al., 2017), 4-year college physics (Rosenzweig et al., 2020), and 2-year college mathematics (Kosovich et al., 2019) when implementing utility-value interventions. The implementation in a 2-year college developmental math course resulted in a 13% improvement in pass rates for men and no difference in pass rates for women (Kosovich et al., 2019).

This study sought to expand upon prior research to understand how a similar intervention would impact community college students in an introductory chemistry course. The research questions were:

1. What effect will a utility-value intervention have on student interest in chemistry in an introductory chemistry course?
2. What effect will a utility-value intervention have on course grades in an introductory chemistry course?

METHODS

The participants in this study were Community College of Baltimore County students enrolled in face-to-face sections Fundamentals of Chemistry (CHEM 107) during the fall 2023 and spring 2024 semesters. This is an introductory chemistry course in which students survey general chemistry topics. Students enrolled in CHEM 107 are predominantly majors in an allied health program, with most of the other students seeking a STEM degree.

Periodically throughout the semester, students completed a homework assignment where they wrote a short essay about a specified chemistry concept. Those in the control group were prompted to write about the topic as if they were explaining it to a fellow student. Their prompt is below, where the blanks would be replaced by the assigned concept:

> "In class, we have been learning about _____. Write an essay that is at least 300 words long that demonstrates your understanding of _____ as if explaining it to a fellow student.

> You should include relevant information from your class notes or textbook expressed in your own words."

Students in the treatment group were prompted to write about how the topic could be used to explain a phenomenon of their choosing. Their prompt is below, where the blanks would be replaced by the assigned concept:

> "In class, we have been learning about _____. Identify a situation you expect to encounter in your future profession that relates to your understanding about _____. If you are not able to identify a situation related to your future profession, you may use a situation from your everyday life instead. Write an essay that is at least 300 words long that applies your understanding of _____ to explain what is happening in the situation that you selected. You should include relevant information from your class notes or textbook expressed in your own words."

Both groups were assigned the same topics: unit conversions, differences between ionic and covalent compounds, molecular shape and polarity, naming compounds, stoichiometry, and solutions. Each writing assignment was completed by a minimum of 82% of the students in the control group and 83% of the students in the treatment group. Students were not given examples of responses nor were the essays discussed in class in order to minimize influence from the instructor.

In addition, during the second week (pre-test) and final week (post-test) of the semester, students completed a modified Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, 1991). This modified version contained only items related to intrinsic goal orientation, extrinsic goal orientation, and task value. Students rated each item on a 7-point Likert scale, ranging from strongly disagree (1) to strongly agree (7). A total of 70 students completed the pre-test, with 43 being in the control group and 27 being in the treatment group. A total of 49 students completed the post-test, with 33 being in the control group and 16 being in the treatment group. A total of 43 students completed both the pre-test and post-test, with 31 being in the control group and 12 being in the treatment group.

Pre-test and post-test results are presented only using the data from students who completed both surveys. Of those students, 25.6% identified as male, 74.4% identified as female, 39.5% identified as white, and 60.5% identified as belonging to an underrepresented minority. Due to the small sample size, Cohen's d effect sizes were calculated rather than tests for statistical significance. Effect sizes are less sensitive to small sample sizes and measure the magnitude of an effect. Following Cohen's guidelines, an effect size of 0.2 is considered small, 0.5 is considered medium, and 0.8 is considered large.

RESULTS

As seen in Table 1, students in both the control and treatment groups had a slightly positive outlook about chemistry at the beginning of the semester. Both groups rated each item similarly, indicating that their motivation at the beginning of the course was similar. The largest differences were for "I think what we will study in Introductory Chemistry is useful for me to know", "What I will learn in this class is relevant to my life", and "I will find the content of this course to be personally meaningful". The first 2 items showed moderate effect sizes (0.65 and 0.76 respectively) and the last one had an effect size just below moderate

(0.47). All 3 items are related to task value and the control group rated them higher in each case.

Table 1. MSLQ Pre-Test Means and Effect Sizes.			
	Control	**Treatment**	**Effect Size**
I think chemistry is an interesting subject.	5.71	5.83	0.10
I am not interested in chemistry.	2.74	2.50	0.15
I will like learning about chemistry in this course.	5.71	5.83	0.05
I think chemistry is interesting.	5.65	5.58	0.29*
I've always wanted to learn more about chemistry.	4.81	4.42	0.24*
I think what we will study in Introductory Chemistry is useful for me to know.	5.52	4.67	0.65**
What I will learn in this class is relevant to my life.	6.00	5.17	0.76**
I will find the content of this course to be personally meaningful.	5.16	4.50	0.47*
I think the field of chemistry is very interesting.	5.61	5.83	0.20*
I think what we will learn in this class will be fascinating.	5.39	5.08	0.24*
To be honest, I just don't find chemistry interesting.	2.65	2.50	0.10
Chemistry fascinates me.	2.87	3.25	0.24*
I think the material in this course will be boring.	5.32	5.25	0.05
I am interested in majoring in chemistry.	2.87	3.00	0.07
MSLQ = Motivated Strategies for Learning Questionnaire * = small effect; ** = moderate effect			

As seen in Table 2, students in both the control and treatment groups had a slightly less positive outlook regarding chemistry at the end of the semester, however both groups still rated each item similarly. In comparison to the pre-test, the post-test results for the items "I think what we studied in Introductory Chemistry is useful for me to know" and "I found the content of this course to be personally meaningful" no longer show any substantial difference between the control and treatment groups. This is due to the rating increasing for the treatment group and decreasing for the control group. The item "What I learned in this class is relevant to my life" was still rated higher by the control group than the treatment group, with a moderate effect size. The items "I think the field of chemistry is very interesting", "I think what we learned in this class was fascinating," "Chemistry fascinates me", and "I think the material in this course was boring" all showed differences between the control and treatment groups, with effect sizes approaching moderate. The treatment group rated the first of those higher, while the rest indicate a more positive perception of chemistry by the control group.

Table 2. MSLQ Post-Test Means and Effect Sizes.			
	Control	**Treatment**	**Effect Size**
I think chemistry is an interesting subject.	5.47	5.67	0.16
I am not interested in chemistry.	3.26	2.83	0.24*
I will like learning about chemistry in this course.	5.26	5.33	0.06
I think chemistry is interesting.	5.48	5.58	0.08
I've always wanted to learn more about chemistry.	4.53	4.67	0.08
I think what we will study in Introductory Chemistry is useful for me to know.	5.29	5.08	0.17
What I will learn in this class is relevant to my life.	5.87	5.08	0.56**
I will find the content of this course to be personally meaningful.	5.06	4.92	0.47*
I think the field of chemistry is very interesting.	5.61	5.83	0.11
I think what we will learn in this class will be fascinating.	5.48	5.17	0.31*
To be honest, I just don't find chemistry interesting.	2.90	2.50	0.28
Chemistry fascinates me.	3.43	2.75	0.52**
I think the material in this course will be boring.	4.84	5.42	0.40**
I am interested in majoring in chemistry.	2.74	3.17	0.22*
MSLQ = Motivated Strategies for Learning Questionnaire * = small effect; ** = moderate effect			

Table 3 compares the average post-test rating to the average pre-test rating for each item. A negative value indicates that the post-test rating was lower than the pre-test rating. Effect sizes were calculated between the control and treatment groups, comparing the magnitude of the change in score. The items "I think what we studied in Introductory Chemistry is useful for me to know" and "I found the content of this course to be personally meaningful" both show an increase from pre-test to post-test for the treatment group and a decrease for the control group. Comparing the changes between each group resulted in a moderate effect size. The items "I think chemistry was interesting," "I've always wanted to learn more about chemistry", and "I think the field of chemistry is very interesting" showed a decrease for the control group, while the treatment group either remained the same or had a slight increase, with effect sizes approaching moderate. The items "Chemistry fascinates me" and "I think the material in this course was boring" both show a decrease in the positive outlook towards chemistry for the treatment group and an increase for the control group, with moderate effect sizes.

Table 3. Differences between MSLQ Post-Test and Pre-Test Means and Effect Sizes.			
	Control	**Treatment**	**Effect Size**
I think chemistry is an interesting subject.	-0.24[a]	-0.17	0.16
I am not interested in chemistry.	0.52	0.33	0.11
I will like learning about chemistry in this course.	-0.39	-0.25	0.11
I think chemistry is interesting.	-0.35	0.08	0.37*
I've always wanted to learn more about chemistry.	-0.27	0.25	0.44*
I think what we will study in Introductory Chemistry is useful for me to know.	-0.23	0.42	0.54**
What I will learn in this class is relevant to my life.	-0.13	-0.08	0.04*
I will find the content of this course to be personally meaningful.	-0.10	0.42	0.45*
I think the field of chemistry is very interesting.	-0.35	0.00	0.31*
I think what we will learn in this class will be fascinating.	0.10	0.08	0.01
To be honest, I just don't find chemistry interesting.	0.26	0.00	0.18
Chemistry fascinates me.	0.56	-0.50	0.52**
I think the material in this course will be boring.	-0.48	0.17	0.44*
I am interested in majoring in chemistry.	-0.13	0.17	0.22*
MSLQ = Motivated Strategies for Learning Questionnaire * = small effect; ** = moderate effect			

Table 4 shows the difference between average post-test and pre-test scores for each group separated by race. For the item "I liked learning about chemistry in this course", white students in the treatment group showed a decrease in average score, while those in the control group showed an increase. Comparing the changes results in a moderate effect size. For the underrepresented minority students, this item shows the opposite trend with a large effect size. For the item "I think chemistry was interesting", the control group showed a decrease for both white and underrepresented minority students. In the treatment group, the white students showed no change, while the underrepresented minority students showed a positive change. Comparing the changes for the white students results in a small effect, while it results in a moderate effect for the underrepresented minority students.

Table 4. Differences between MSLQ Post-Test and Pre-Test Means by Race.						
	White			Underrepresented Minority		
	Control	Treatment	Effect Size	Control	Treatment	Effect Size
I think chemistry is an interesting subject.	0.20	-0.57[a]	0.61**	-0.67	0.20	0.82***
I think chemistry was interesting.	-0.30	0.00	0.22*	0.38	0.20	0.54**
I found the content of this course to be personally meaningful.	-0.10	0.29	0.34*	-0.10	0.60	0.59**
I think the field of chemistry is very interesting.	0.00	0.14	0.13	-0.52	-0.20	0.26*
To be honest, I just don't find chemistry interesting.	0.20	-0.14	0.26*	0.29	0.20	0.06
Chemistry fascinates me.	1.00	-1.00	1.22***	0.35	0.20	0.01
MSLQ = Motivated Strategies for Learning Questionnaire a = negative values indicate the pre-test rating was higher than the post-test rating * = small effect; ** = moderate effect, *** = large effect						

Like the previous item, "I found the content of this course to be personally meaningful" showed a decrease for all students in the control group and an increase for all students in the treatment group. There was a larger increase for the underrepresented minority students, showing a moderate effect, while there was a small effect for the white students. For the item, "I think the field of chemistry is very interesting", there was no substantial difference between the changes for the control and treatment groups for the white students. The underrepresented minority students showed a decrease in their ratings for both control and treatment groups, but the treatment group had a smaller decrease with a small effect size. For the item "To be honest, I just don't find chemistry interesting", white students in the treatment group showed a decrease in score – indicating that they found chemistry more interesting – while those in the control group found chemistry less interesting at the end of the semester. The underrepresented minority students found chemistry less interesting in both the control and treatment groups, with no substantial difference between them. For the item "Chemistry fascinates me", white students in the control group showed a large increase while

those in the treatment group showed a large decrease with a large effect size. Underrepresented minority students showed an increase in rating for both control and treatment groups, with no substantial difference between them.

When comparing overall course grades between the control and treatment groups, with a 0 indicating an F and a 4 indicating an A, the average final grade was 2.48 for the control group and 2.75 for the treatment group. This has a small effect size of 0.22.

DISCUSSION AND CONCLUSION

When comparing the pre-test and post-test scores for "I think what we will study in Introductory Chemistry is useful for me to know" and "I will find the content of this course to be personally meaningful" it is interesting to note the difference between the control and treatment group was larger on the pre-test. This difference had a moderate effect size, while on the post-test there was no substantial difference between the control and treatment groups. The reason for this change is that the average score on the post-test for these items increased, while they decreased for the control group. This indicates that the treatment had some positive effect on students' task-value motivation. It is further supported by the moderate effect sizes for the differences between the post-test and pre-test, as seen in Table 3.

When comparing the pre-test and post-test scores for "I think chemistry was interesting", "I've always wanted to learn more about chemistry", and "I think the field of chemistry is very interesting", the control group decreased while the treatment group either increased or remained constant. These all had effect sizes approaching moderate, which indicates that having students try to make connections between the chemistry content and their personal interests had a positive effect on their interest in chemistry. Since this is an introductory chemistry course, it is possible that many of the students had little prior experience connecting chemistry content to their personal interests and goals. Having the students reflect on the relevance of the content seemed to improve their perceptions of chemistry.

Given those positive effects, it is somewhat perplexing that when comparing pre-test and post-test scores for "Chemistry fascinates me" and "I think the material in this course was boring", the treatment seemed to have a negative effect. Students in the treatment group found chemistry less fascinating and the course material more boring at the end of the semester, while students in the control group were the exact opposite. The connections that students made to chemistry were not incorporated into the course and it is possible that incorporating them may increase the students' motivation in the course.

When comparing the effect of the treatment for white students and underrepresented minority students separately (see Table 4), it appears that overall there was a larger positive effect for the underrepresented minority students. Their ratings showed a larger positive change or a smaller negative change when compared to white students. This is consistent with prior research conducted in biology classrooms (Harackiewicz et al., 2016).

The small sample size of students in this preliminary study limits the generalizability of the findings, but these results, along with prior studies, indicate that having students make connections between the course concepts and their future careers or daily lives improves their motivation, which may lead to an improvement in course grades. Prior work has focused on instructor-generated examples to demonstrate the relevance of content, but more work should be done exploring the effectiveness of

having students generate connections for themselves. While instructors have the extensive disciplinary knowledge to see the relevance of their field in many different contexts, it is not practically possible to show connections that will be relevant to all students. In addition, discovering how course content is connected to personal or professional interests for oneself is potentially more meaningful than being told that information in a classroom setting.

In this study, the treatment group had a higher overall course grade than the control group, which is also consistent with prior work (Harackiewicz et al., 2016). In addition, there seems to be a larger effect for the underrepresented minority students, which may aid in reducing the achievement gap. While the context for this study was a chemistry course, having students write about how the material they are learning relates to their lives should be applicable for any subject. Future studies could explore the types of connections students make, incorporating the student-generated connections into the course in the same semester, and/or having students share their connections with their peers.

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