Improving Undergraduate Students' Chemistry Self-Efficacy Through Metacognitive Training

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Self-efficacy is a concept originally developed in the field of psychology and is defined as one's belief that they can complete a certain task or goal. In education, self-efficacy is one affective characteristic that students have that can affect their success in the classroom, so teachers need to be aware of it to help students persevere through STEM courses. Interventions to affect students' self-efficacy have been attempted in the literature, many showing an increase in students' chemistry self-efficacy, including metacognitive student skills training. Therefore, this research paper addresses if metacognitive tutoring sessions affect students' chemistry self-efficacy. Tutoring sessions that covered metacognitive study strategies were implemented with eleven organic chemistry two students at a community college. Students who participated in the intervention had more increased chemistry self-efficacy after the intervention than those who did not participate, based on pre/post surveys and qualitative interviews. By teaching students study skills based in metacognition, chemistry educators can better help their students to be confident with the material, hopefully leading to higher performance in chemistry courses and a stronger retention of students in chemistry courses and STEM careers.

Self-efficacy is a concept established by Bandura (1977) as part of his social cognitive theory. Self-efficacy is a belief that oneself can achieve a specific outcome or objective (Bandura, 1977). This affective characteristic is domain-specific; academic self-efficacy does not apply to all classes, and high chemistry self-efficacy does not mean someone will have high physics self-efficacy, for example (Bandura 1977; Moreno, 2021). Since a student's self-efficacy is a measure of how well a student thinks they will be able to complete certain tasks, researchers have hypothesized and shown that students who have a higher self-efficacy perform at a higher academic level (Bandura 1981).

The connection between self-efficacy and academic performance makes understanding students' self-efficacy a critical area of study in higher education. Understanding students' self-efficacy allows instructors to gauge students' confidence with chemistry topics and how well they will perform. For STEM courses, which are often quite challenging and can cause many students not to pursue a STEM career, understanding students' STEM self-efficacy can help instructors gauge whether students will persevere with STEM. In undergraduate chemistry classrooms specifically, multiple researchers have found that high academic performance in chemistry is correlated with high self-efficacy scores (Moreno, 2021; Ramnarain & Ramila, 2018; Wilson-Conrad 2018). Given the correlations between academic performance and self-efficacy, multiple researchers have studied interventions in chemistry classrooms and labs to impact students' self-efficacy and performance through problem-based learning (Mataka & Kowalske, 2015), flipped classrooms (Naibert et. al. 2021), and metacognitive training (Gamby and Bauer, 2022; Graham et. al. 2019). This research indicates that there is a connection between students' chemistry self-efficacy and academic performance as found through quantitative means. Therefore, there is a need for more qualitative research to better understand the connection between academic performance, student understanding, and chemistry self-efficacy with undergraduate chemistry courses and diverse undergraduate students.

The research question this study aims to address is how metacognitive tutoring sessions affect students' chemistry self-efficacy? The literature review presents the research in self-efficacy in chemistry higher education and what interventions have been used to affect it. The methods section describes the design of the intervention and its participants. The results and findings section discusses both the results of the pre/post self-efficacy survey as well as excerpts and findings from the student interviews. The implication and conclusion sections summarize the findings and provide educators from all disciplines ways they can utilize the findings in this study.

Review of Literature

The literature review is divided into two main sections. First, the connection between self-efficacy and academic performance that researchers have established in specific contexts is explored. Then the interventions that science education researchers have used to affect students' self-efficacy will be presented.

Self-efficacy and academic performance

Bandura's original review of his self-efficacy research was with psychology patients with phobias (Bandura, 1977). His research showed that patients' self-efficacy predicted their performance on tasks better than past performance did. Bandura found self-efficacy information came from four different sources: mastery experience, vicarious experience, verbal persuasion, and physiological reaction. Mastery experience refers to a person successfully completing a task in the past, which can increase their self-efficacy related to that task. Vicarious experience is seeing other people successfully complete the desired task, which encourages the person that they can also succeed if they are persistent. Verbal or social persuasion is convincing someone through social interactions they can achieve a task. Finally, physiological reactions are the ways in which people respond to a given situation; increased anxiety will make a person more likely to think they are incapable of succeeding with a task. Of all four sources, Bandura found mastery experience to be the main source of patients' self-efficacy (Bandura, 1977).

Research into self-efficacy in college science classrooms has been both quantitative and qualitative (Flaherty, 2020). Quantitative scales measuring self-efficacy have been created for different types of general and organic chemistry college classrooms. Using these scales and other means, researchers have explored the connection between students' self-efficacy scores and their exam performance (Villafañe et. al., 2016; Willson-Conrad & Kowalske, 2018). Both Villafañe et. al. (2016) and Willson-Conrad & Kowalske (2018) investigated performance on exams as compared to students' self-efficacy, and the researchers found students with higher self-efficacy generally performed better on chemistry exams and had lower test anxiety. Willson-Conrad & Kowalske (2018) found, via interviews, their highest performing students in general chemistry exams had high chemistry self-efficacy due to mastery experiences (i.e. previous success with chemistry content) while middle performing students obtained self-efficacy beliefs from vicarious experience (i.e. comparing their exam scores to their peers to evaluate their perceived ability). Villafañe et. al., (2016) found pre-exam organic chemistry self-efficacy scores predicted students' exam performance, and exam performance had positive effects on self-efficacy, indicating that mastery experience is a major source of students' self-efficacy.

Other studies found chemistry self-efficacy could be correlated to overall academic performance. The College Chemistry Self-Efficacy Scale has been used in chemistry higher education in both the United States (Ferrell et. al., 2015) and South Africa (Ramnarain & Ramila 2018) and has been found to be a reliable way to predict students' chemistry self-efficacy. Using this scale, these same groups have also found that self-efficacy was able to predict students' final course grade (Ferrell et. al., 2016) or final cumulative exam score (Ramnarain & Ramila 2018). Chan and Bauer (2014) have also confirmed that students with high self-efficacy (as measured by examining students' motivation) tend to perform better in their college chemistry courses. When Moreno et. al. (2021) looked at multiple factors (i.e., gender, SATM score) to predict students' course GPA in introductory and general chemistry courses, they found post-test chemistry self-efficacy scores best predicted GPA. These studies are examples that, according to pre- and post-course data from chemistry self-efficacy scales, students with higher self-efficacy perform better in chemistry courses than students with lower self-efficacy.

While the above studies show a clear connection between self-efficacy and academic performance, there are other factors to consider. First, the positive correlation between performance and self-efficacy has not always meant that self-efficacy increases linearly (Villafañe et. al., 2016). Average self-efficacy scores in this study fluctuated throughout the semester, which meant students' self-efficacy did not only increase with further chemistry instruction. However, this trend would not be possible to observe in other cases, as most researchers only assessed self-efficacy at the beginning and end of the course, which does not allow students' self-efficacy across a semester to be evaluated (Villafañe et. al., 2016). Second, self-efficacy has not always been found to be the best predictor of course performance. Gibbons & Raker (2019) found that self-concept, not self-efficacy, was the best predictor of exam performance. While not in a chemistry context, McBride et. al. (2020) evaluated non-science majors' science self-efficacy at a liberal arts college and found their science self-efficacy was not the best predictor of their academic performance. These examples point out the exact connection between chemistry self-efficacy, academic performance, and student understanding is still not entirely understood. Therefore, research on self-efficacy, particularly in tutoring settings, may provide a valuable contribution to understanding the link between the effects that chemistry self-efficacy has on academic performance and vice versa.

Interventions that affect self-efficacy and metacognition

There have been both classroom- and electronic-based interventions implemented in college science and chemistry courses to determine the effects on students' self-efficacy. Naibert et. al. (2021) found general chemistry one and two students had improved chemistry self-efficacy scores after a semester of flipped classroom instruction. Mataka & Kowlaske (2015) found students who took general chemistry courses with a problem-based learning unit had a higher chemistry self-efficacy after the course, and interviews after general chemistry two revealed the increase was due primarily to the PBL unit. Amelink et. al. (2015) found community college STEM majors who attended a summer research internship in their field of study had improved research self-efficacy from all four sources of self-efficacy, based on students' reflective journal entries. In one specific example, the researchers found the mentoring the students received from the professors and graduate students provided a boost to students' self-efficacy via vicarious experience (Amelink et. al., 2015). These are only a few examples of the interventions that have been implemented, clearly showing that there are a variety of ways to impact students' science self-efficacy.

Another intervention used by multiple groups is metacognitive training. Since metacognition is considered an aspect of self-regulated learning, it makes sense that improving students' metacognition would help them to be successful in achieving their goals of being successful in chemistry (McDowell, 2019). Teaching science students about metacognition has been shown to increase students' success in the courses, as well as their self-efficacy (Graham et. al., 2019). Graham et. al. implemented weekly tutoring sessions as part of a general chemistry course that combined teaching metacognitive skills and ways for students to use those skills in a chemistry context. They found students who received the training scored higher in self-efficacy than those who did not, and the gap in self-efficacy between men and women was eliminated with the training (Graham et. al., 2019). In another example, Gamby & Bauer (2022) implemented an online module in a general chemistry one course at a community college that focused on metacognition, which was found to give students explicit metacognitive knowledge that they implemented in the course and in their life. Finally, Cook et. al. (2013) incorporated a fifty-minute lecture about metacognition and how it could help students with their general chemistry course. They found students who attended the lecture achieved an entire letter grade higher than their peers who did not attend the lecture. These examples show metacognition is a promising way to promote student self-efficacy and that it has the potential to improve students' course performance as well. Providing metacognitive instruction in a small group setting could be an effective intervention to positively affect students' chemistry self-efficacy.

The research question this study aims to address is: how can teaching students metacognitive skills during tutoring affect community college students' chemistry self-efficacy? Since metacognitive instruction has been found to both increase chemistry self-efficacy (Graham et. al, 2019; Gamby & Bauer, 2022) and chemistry course grade (Cook et. al., 2013), this seems to be a promising route that deserves more exploration into how it affects students' chemistry self-efficacy and academic performance. While there have been a variety of studies related to chemistry self-efficacy, very few have been done with community college students (Amelink et. al., 2015; Gamby & Bauer, 2022). Considering that many URM students attend community colleges, and there is a gap between URM's representation in the general population and in STEM careers, it's important to find ways that can help URM students remain in STEM (Amelink et. al., 2015). There is also a lack of qualitative data about college students' chemistry self-efficacy (Flaherty, 2020), which this study aims to fill by interviewing students to get a more nuanced view of their self-efficacy.

Methods

A mixed-method approach was used to evaluate how metacognitive study skills taught during tutoring sessions would impact students' chemistry self-efficacy. The study took place during the Spring 2023 semester, which runs from Jan through April. A pre/post survey was used to assess students' chemistry self-efficacy before and after the intervention. Through interviews, sources of students' self-efficacy were explored to identify what sources majorly contribute to students' chemistry self-efficacy.

Setting

The setting of this study is University of Cincinnati-Blue Ash, which offers associate degrees and other degrees in health-related programs. The students who participated in this study were from Dr. G's second semester organic chemistry course (referred to as organic chemistry two in the rest of this work). Dr. G runs a flipped classroom, where students fill in guided notes outside of class and do practice problems in groups during class. Supplemental videos are provided to students after they have completed and turned in the notes for a particular section. Dr. G also emphasized some metacognitive strategies during her organic chemistry one course the previous semester. Organic chemistry two is required for many science majors, including biology, chemistry, and other health science-related majors. All intervention lessons and interviews were conducted outside of the organic chemistry two class time.

Researcher information

The researcher is a chemistry tutor in the Science Learning Lab at UC-Blue Ash. At the time of the study, the researcher was in her second year of work as a tutor. The center is a drop-in service that is free for all students at the school. The researcher works with students individually or in small groups who come in with questions about class content, homework problems, or lab work. The researcher works with students who have a variety of different nationalities, ethnicities, ages, genders, and majors. She tries to use a variety of strategies to effectively work with this diverse student population.

Participant information

The participants were recruited by the researcher visiting Dr. G's organic chemistry two class to tell the students about the study and what it would entail. Students had approximately one week to sign up for the study. Additionally, the students learned more about the study by talking to the researcher when they were in the tutoring center. Students were not offered any point or grade incentive for participating in the intervention. Those who did not participate in the intervention were the control group. The participants in the metacognitive lesson intervention were eleven students from Dr. G's organic chemistry two class. Seven identified as women and four identified as men. All except two students reported they came to the tutoring center daily or multiple times per week. All had taken organic chemistry one the previous semester at the same college, three with the same teacher and eight with a different one. The eleven participants in the control group only completed the pre and post survey and were not given any metacognitive instruction. The control group had ten women and one man, all of whom completed organic chemistry one at the same institution. Only one person regularly visited the tutoring center and six respondents said they had never visited the tutoring center since Fall 2022.

Survey

A pre/post survey was used to measure students' self-efficacy related to organic chemistry (see Appendix Table A1). The questions asked students how confident (1=least confident, 5=most confident) they felt about major topics from organic chemistry one, which they would have to continue to apply in organic chemistry two. These surveys were administered via Socrative, an online quiz platform, during class periods. The teacher offered two points of extra credit on the students' next quiz score to complete each survey. The pre-self-efficacy survey was given on Jan 25, 2023, before all students had committed to the intervention. The post-self-efficacy survey was given after all lessons and interviews had been completed on Feb 22, 2023. For those not in class the day the surveys were provided, they were given the option to complete a paper survey before the next class period.

Intervention-Study Skills Lessons

To answer the research question, metacognitive study skills sessions were taught to 11 community college students taking the second semester of organic chemistry. There were three lessons that each student attended that took place between weeks 3-7 of their Spring 2023 semester. The lessons were 20-30 minutes long, and students participated individually or in groups of 2-5 students, depending on scheduling. The lessons focused on four metacognitive strategies and how students could use them in their organic chemistry two course. The material was drawn from the Learning Scientists blog (Caviglioli et al, n.d.), a website utilized in the Graham et. al. (2019) study. Specifically, students were sent one or two short videos one day before each lesson that they were told to watch prior to the lesson. During the lesson, PowerPoint slides from the Learning Scientists website were used by the researcher to discuss the different metacognitive study strategies. Lesson one covered retrieval practice and spaced practice, lesson 2 covered elaboration with a focus on concept mapping, and lesson 3 covered interleaving. Throughout each PowerPoint, the researcher discussed ways the metacognitive study practices could be used for organic chemistry, and students provided their thoughts about applying them into their study routines. After each presentation, the students completed an exit slip, which involved answering questions or submitting an example of what had been discussed during the lesson. This allowed the researcher to see what the students learned from the lesson and what they saw as important.

Interviews

Two interviews were conducted with the eleven students involved in the intervention. The purpose was to gain more qualitative data from students, as well as to identify common sources of self-efficacy. Ten students participated in interview one, and all eleven students participated in interview two. Each interview was recorded either on the researcher's phone as an audio recording, or over Zoom if the interview was virtual; verbal consent for recording was obtained from each participant before proceeding. Interview one was conducted the week before the students' first organic chemistry test of the semester. Each interview was individual and was 10-20 minutes. Six main questions were asked, as well as follow-up questions based on students' responses. Questions were related to students' study strategies for the upcoming tests, as well as questions about any test related anxiety they might have. Interview two was conducted at least one day following students' final metacognitive lesson. Seven different questions than the first interview were asked related to students' incorporation of the metacognitive study strategies and their feelings after the first test. Again, follow-up questions were asked based on students' initial responses (see Appendix Table A2 for initial questions for pre- and post-interviews).

Results and findings

Survey results

Organic chemistry self-efficacy survey data was collected before and after the intervention to determine if the intervention affected the self-efficacy of students in the experimental group. Of the 26 original students in the class, 23 students took the pre-survey, and 24 students took the post-survey. One student dropped out of the class between the pre and post survey but did not take the initial survey. 22 students who took the pre-survey also took the post survey; the remaining two students who took the post-survey did not take the pre-survey. Therefore, only the data from the 22 students who took both surveys was used in the analysis.

Table 1: *Average change in students' self-efficacy for the experimental and control groups*

Group	Pre survey	Post survey	Average change	Average % change
Control	3.46	3.54	0.08	+2
Experimental	3.66	4.07	0.41	+11
Overall	3.56	3.81	0.25	+7

After students completed both surveys, the average results for the pre and post surveys were calculated for the overall class and for each group of students (control and experimental). The results per student are presented in Table A3, as well as the average change and percent change from pre to post survey. Overall, most students' self-efficacy scores increased from pre to post test. However, five students in the control group had a decreased self-efficacy score. One student in the experimental group had their self-efficacy score decrease slightly while two more in the group had unchanged self-efficacy. Table 1 shows the average increase in self-efficacy score for the control group was 2% while for the experimental group it was 11%. This indicates that, on average, students who participated in the metacognitive study strategies intervention had an increased organic chemistry self-efficacy after the intervention, even more than the control group. Students in the experimental group also had some of the biggest changes in self-efficacy, with one student increasing their score by 29% from pre to post survey. Further qualitative results will be discussed in the sections below to support the findings that students felt more confident in organic chemistry because of the study skills they learned.

Study skills lessons

All eleven students in the experimental group completed three metacognitive lessons that covered four specific study strategies: retrieval practice, spaced practice, elaboration, and interleaving. PowerPoint presentations put together by the creators of the Learning Scientists blog were used by the researcher to share these study strategies with the students (Caviglioli et al., n.d.). Students overall had positive reactions to learning the study skills. They asked questions about how to incorporate these study strategies in organic chemistry specifically, which sparked helpful and productive conversations about specific applications of the strategies.

The exit slips the students were given after the first lesson was to see if and how they thought they might use spaced and retrieval practice in their studying. All students gave various ways they could try incorporating the study strategies, showing they had understood and were interested in strategies discussed during the lesson. During the second lesson students saw an example of a concept map the researcher had created based on an organic chemistry concept. The exit slip after the second lesson required students to create a concept map related to an organic chemistry term they had recently covered, aromaticity. Even though some students had never heard of or created a concept map before, they all attempted to create one for five minutes at the end of this lesson. After working on it, the researcher talked with the student(s) about what they created and what connections they made. Each student had very different ideas about how to connect ideas together. It gave the researcher the chance to see how the students were making connections between ideas and to identify any misconceptions. Multiple students said they found it challenging but would still attempt to make concept maps for other organic chemistry topics. The exit slip after the third lesson asked students how they would use interleaving and if students were planning to use other strategies throughout the semester. Many students expressed interest in using interleaving as a strategy, and all students said they planned to use at least one study strategy for the rest of the semester.

Interviews

Pre exam interviews. The pre-exam interviews were conducted with ten students from the experimental group prior to the first exam (one student couldn’t be interviewed due to scheduling conflicts). The purpose of this interview was to ask students how they prepared for chemistry exams and their general feelings toward their exams. An important note is the majority of the students (eight out of eleven) had a different professor for the first semester of organic chemistry than in the second semester. The other professor implemented quests instead of exams, which were shorter assessments students could take multiple times to pass, and students had only one full length final exam. Therefore, the students who took the class with the other professor did not have much experience preparing for long organic chemistry assessments.

Overall, students reported feeling confident they could be successful on their exam based on their past experience in taking chemistry tests. Even students who had only taken short organic chemistry assessments felt confident they could succeed, due to a mixture of doing well on the quests and doing well on general chemistry exams from prior semesters. When they were asked what study strategies they were using and were going to use to prepare for exam one, many students shared that they were already incorporating spaced practice and retrieval practice from the first lesson. One common way that students were doing this was through flashcards, which had been discussed as a way to both help memorize the products of the reactions without mechanisms and to write down the mechanisms for reactions that had them.

The students were also asked if they liked to work with other students when studying. Many students actively planned to meet with others for a variety of reasons. One reason was to help each other when someone in the group didn't know how to do something. Student 10 described it as if "they [another student] don't know something, I'm able to explain and then I see how well I know the material explaining it to them. And then I'm like, yeah I actually I get it. I got the material because I'm able to explain it to you." Some students described that they liked to work in groups because of the support they felt. Student 6 described the support they could provide each other as "validation that if we both don't know something, it's ok, at least I'm not the only one who is completely lost on this specific topic". Feeling like they aren't alone in not understanding things makes some students feel supported and helps them believe they can work through it together. An important point is that some students said the main way they work with others is in the tutoring center. They wouldn't necessarily make plans to work with other students, but they knew when their classmates would be studying in the tutoring center, so they could end up working together. This is an important note because the only two students who did not like to work with other students at all were students who rarely come to just study in the tutoring center. From the interviews, it seems like part of the reason they don't come to the tutoring center is that they would rather work alone than in groups, so they don't see the need to be around a lot of people when studying. They both mentioned that barriers to working with others were noise from students working together and wanting to understand things fully before interacting with others.

Students were asked about their past experiences with test anxiety in previous chemistry courses. Many students said they felt anxious about their chemistry tests before, during, and after the test. While some students reported not feeling as anxious last semester when they were taking lower stakes quests, they still expected to feel test anxiety for their upcoming test based on previous chemistry classes. Some students worried that they would not know everything that they would see on the test, so they would get overwhelmed and stuck on problems they didn’t know how to do. Others worried about overthinking problems and second guessing themselves, which increased their anxiety. Student 4 describes this, saying “I just get even more anxious because I know the answer, but I'm second guessing myself so that just puts even more pressure on me.”

Students also provided ways that they cope with the anxiety. They mentioned taking deep breaths, telling themselves they can do this, and writing on the top of their paper “don’t second-guess yourself”. Others spoke about going into the exam with a better attitude, so that they will get the desired result. Student 5 reported not feeling much anxiety around tests because of the attitude he had when taking the exam, as he described: “If you go in there thinking you're gonna do good, you'll do good. You go in thinking you're gonna do bad, you're gonna do bad. So go in thinking you're gonna do good.” Overall, while most students did feel anxiety about exams, many had methods to prevent it from becoming overwhelming during the exam.

Post-interview interviews. The second interview was conducted after students had completed the three study skills lessons. These interviews were conducted to ask how students felt after the first test and to understand how students’ study strategies had changed after learning all of the metacognitive study skills. Most students felt pretty confident that they did well right after the test. The most common comment was students worrying about questions they weren’t sure if they completed correctly, so they sought help from other students or tutors after the test to ask if what they did was correct. Once students got their score back, most found that the score matched or almost matched how they felt after the exam. All eleven students personally met with the instructor to seek feedback after the exam; some did so only because they gained two extra credit points on the test by doing so, while others wanted to understand in more detail what they did wrong. Most students who went for the latter reason thought the opportunity for feedback was very helpful, but the biggest complaint was that they could not keep their test or take exact notes about what they did wrong.

When students were asked if they had started to incorporate the metacognitive strategies into their study routine, most said they had at least tried some of the strategies. Many said the strategies made them feel like they knew more of the material and were confident with it. Student 5 said, "I guess like the things we are learning are actually working. I'm going to keep using them. I'm probably going to keep using them until I graduate to be honest." Even in the short few weeks of the study, he had already found the strategies to be something he would continue to utilize for future classes beyond only chemistry. The most common obstacles to students incorporating the new strategies were time management and the difficulty of changing the study methods they had already established during college. Some students had heard about some of the metacognitive strategies before, by a different name, but most students had no exposure to these strategies prior to the intervention. Some students did not know appropriate ways to study. Student 9 admitted, "I thought that cramming was what you were supposed to do… because that's what everyone does usually." These strategies provided him with more effective ways to learn the material and remember it long term.

Most students reported their anxiety in their organic chemistry class went down after learning the strategies. Some even commented that the two strategies they learned the week before the test already helped to alleviate some test anxiety. Student 4 said, "I learned many ways to study, which gave me more confidence on my ability on doing problems on my own, during class and when I'm doing homework and on the exam…I think just having more confidence decreases my anxiety." The study strategies provided her with a variety of ways to practice the material and gave her more confidence, helping to reduce her anxiety. Most said that they didn't let any anxiety they had during the exam affect how they took the test. Others shared that they still struggled with anxiety during the test, due to low self-confidence in their ability to succeed.

The last question students were asked in this interview was if they had any mentors who helped them feel successful in chemistry. A few students said one of their parents was a mentor by believing in them or helping them with some concepts. Others mentioned the researcher and the other chemistry tutor in the tutoring center were mentors who helped them feel like they could succeed in chemistry. Student 6 described the tutors as people who would "always talk me down after I think that I did really bad. And it never turns out that way." She also mentioned that having the tutors double-check her work and tell her she was approaching the problem correctly bolstered her confidence. Some students mentioned that previous chemistry teachers were encouraging mentors. Overall, most students had mentors who influenced how they felt about chemistry.

Connections to sources of self-efficacy

Based on students' first and second interviews, students' feelings of self-efficacy do not come solely from one source. Some students felt like they could be successful based on their past experiences in chemistry courses, which is an example of mastery experience. It is important to acknowledge that students who did not have experience with organic chemistry tests from the previous semester had less large assessment experiences to draw on, so there were not as many students who said their past experience with chemistry made them more confident as might otherwise have been expected.

Nine of eleven also reported working with other students helped them feel like they could be more successful in organic chemistry. Based on students' responses, working with others were examples of both vicarious experience and social persuasion; vicarious because students can see other students successfully completing the tasks and social because their peers were providing encouragement to support their success. It is important to note students already had experience working with each other in groups during class time, both last semester and this semester, as both professors utilized the flipped classroom approach. Students' comments indicate the importance of encouraging students to work together to bolster students' self-efficacy (in most cases) through watching others complete the task and through encouragement.

The number of times students brought up feeling anxious about assessments or the class as a whole indicates anxiety is an important factor to consider how it affects students' self-efficacy. Anxiety is one example of a physiological reaction that negatively impacts students' self-efficacy. Students who let their anxiety impact their exam performance tended to be those with lower self-confidence in their exam taking abilities. Those who were able to overcome their exam anxiety had established strategies, either physical or mental, that helped them overcome their anxiety to feel more confident in their abilities.

A question about students' chemistry mentors was asked because of findings in STEM research self-efficacy that mentors could be an example of vicarious experience (Amelink et. al, 2015). While this was the question most students had the shortest response to, multiple students reported they had mentors who affected their belief they could be successful in chemistry. Some students even said the tutors at the college campus, including the researcher, had been mentors who gave them confidence that they could be successful. This illustrates the importance of having tutoring centers or other mentors who are not the professors grading the students to bolster students' self-efficacy.

Limitations

This study had some limitations. First, it was done in the span of five weeks. Therefore, it is hard to tell how much students' self-efficacy and study habits really did change in such a short time period and if those study habits would be continued throughout the course. Second, there was a bias in the sample used because most students who joined the study already knew the researcher. Therefore, they were more willing to try the strategies because they had already established a tutor-student relationship with the tutor. Third, the pre/post self-efficacy surveys might not have accurately captured students' true feelings of self-efficacy. Since students were only given surveys at two time points, their responses could have been highly dependent on their feelings or experiences that day. Additionally, the questions on the survey could have impacted students' answers. Students were told to base their answers on their organic chemistry semester one knowledge. This was because putting questions from what students would learn in organic chemistry two on the pre survey would cause an automatic difference between pre and post-test. The questions were also chosen because they were concepts that continued to be used and built upon in organic chemistry two, so it was suspected that students should feel slightly more confident with those concepts by the post-test.

Conclusions and Implications

The results from the study showed that, when students learn and utilize metacognitive study skills, their self-efficacy tends to increase in most cases, more so than those who did not learn the study skills. Interviews with students revealed that the study skills made them feel more confident with organic chemistry concepts in general and reduced anxiety for assessments. The interviews also revealed that students' feelings of self-efficacy come from a variety of sources, including working with their peers and test anxiety. While other studies have found that mastery experience is usually the main source of self-efficacy for students (Wilson-Conrad & Kowalske, 2018), this study found that many students' confidence and self-efficacy was dependent on their anxiety (physiological reaction). This confirms what one study found, that, based on qualitative data provided by students, their sources of self-efficacy can be more complex (Amelink, 2015). The findings answer the initial research question because it gives insight into how teaching metacognitive study skills affected students' self-efficacy.

This study has implications for those working in higher education in all disciplines. Metacognitive study skills are an important way to help students feel more confident with a subject, as they provide students with effective study strategies that many students are not aware of (Muteti et. al., 2021). Professors can promote these skills with their students by spending some time discussing specific study skills with students during class times, especially before assessments, and show them how these strategies can be utilized for that specific course. Professors should also be aware of students' assessment anxiety and ways that they can help alleviate anxiety, so students are not as affected by it when taking assessments. Professors can also encourage students to work in groups, so that the support and encouragement they receive from their peers can increase their confidence. For those working with students in higher education but not in a traditional classroom, being a mentor to students and supportive of their success is very important. Mentoring can positively affect students' self-efficacy if mentors are encouraging and help students to feel confident in their knowledge. Overall, this study provides valuable insights into how metacognitive study skills can affect students' self-efficacy and from what sources college students' self-efficacy arise.

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Appendix

Table A1: ***Self-efficacy survey questions. Questions 10-13 were asked on the pre-self-efficacy survey only.***

These questions are based on your knowledge of organic chemistry. On a scale from 1 to 5 (1=least confident, 5=most confident), how confident are you that you can:

1.	Recognize a functional group in an organic molecule?	1	2	3	4	5
2.	Use the structure of an organic molecule to predict its strength as an acid or base?	1	2	3	4	5
3.	Draw organic compounds when given their IUPAC name?	1	2	3	4	5
4.	Draw all resonance structures of an organic molecule?	1	2	3	4	5
5.	Identify the differences between enantiomers, diastereomers, and constitutional isomers?	1	2	3	4	5

6.	Predict the products of organic chemistry reactions?	1	2	3	4	5	
7.	Draw a mechanism (that you learned) for organic chemistry reactions?	1	2	3	4	5	
8.	Develop a synthesis when given a starting material and target product?	1	2	3	4	5	
9.	Determine the mechanism (substitution or elimination) for a given organic reactant and set of reagents?	1	2	3	4	5	
10.	How do you identify?	Man	Woman	Non binary	Other	Prefer not to say	
11.	When did you take organic chemistry 1?	Fall 2022	Spring 2022	Fall 2021	Spring 2021	Before 2021	
12.	Where did you take organic chemistry 1?	At UC Blue Ash	At UC Clermont	At UC main campus	At a different school		
13.	How often have you been to the Science Learning Lab in Walters 200 since the beginning of Fall 2022 semester?	Daily or multi ple times a week	Once a week	A few times a month	Once a month	Less than once a month	Never

Table A2: ***Pre-exam and post-intervention interview questions***

	Pre-exam interview questions
1.	How did you usually prepare for chemistry exams prior to this semester?
2.	What study strategies to do you plan to use to prepare for this organic chemistry exam?
3.	Based on your previous chemistry classes, do you feel confident that you will be successful on this exam?

4.	Do you plan to study with others to help prepare for this exam? Why or why not?
5.	Do you plan to seek feedback from the teacher about your exam score after the test? Why or why not?
6.	Do you get test anxiety before, during, or after taking the test? If so, how does that affect how you take the exam?

Post-intervention interview questions	
1.	How do you feel like you did on the exam?
2.	Did you follow some of the strategies you mentioned in the first interview? If so, what did you use and do you feel like the strategies helped you?
3.	Did you have any difficulties in implementing the metacognitive strategies into your study routine? If so, what was difficult?
4.	Had you heard of any of these metacognitive strategies before I taught them to you?
5.	Do you feel like any test anxiety affected your performance on the exam? If so, how?
6.	Do you feel like any of the metacognitive strategies helped to reduce your anxiety level (on the test or subsequent quizzes)? If so, how?
7.	How have any mentors, if any, made you feel like you can be successful in chemistry? These could be mentors from before college or during college?

Table A3: ***Pre- and post-self-efficacy survey were administered 5 weeks apart.***

Student	Gender	Pre-survey	Post-survey	Difference	Change in self-efficacy (%)
		Experimental group			
1	F	4.22	4.67	0.45	11
2	M	4.78	4.67	-0.11	-2
3	F	3.22	3.67	0.45	14
4	F	3.78	4.22	0.44	12
5	M	2.89	3.33	0.44	15
6	F	3.89	4.78	0.89	23
7	F	3.44	4.22	0.78	23
8	F	4.33	4.33	0	0
9	M	3.67	3.67	0	0
10	F	3.33	3.78	0.45	14
11	M	2.67	3.44	0.77	29
		Control group			
12	F	3.78	4.33	0.55	15
13	F	2.78	2.89	0.11	4
14	F	3.33	3	-0.33	-10
15	F	3.67	3.33	-0.34	-9
16	F	3.33	3.78	0.45	13
17	F	4.00	4.44	0.44	11
18	F	3.00	3.33	0.33	11
19	F	4.22	4.11	-0.11	-3
20	M	3.89	4.33	0.44	11
21	F	2.89	2.78	-0.11	-4
22	F	3.22	2.67	-0.56	-17