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Implementation and Assessment of a Course-Based Undergraduate Research Experience (CURE) in General Chemistry

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Chapter 1: Introduction

Introduction to CUREs

Course-based undergraduate research experiences, known as CUREs, have been explored and implemented in many institutions due to national calls to engage more STEM undergraduate students in doing research.[1] One of the earliest published peer-reviewed manuscripts on a research-embedded undergraduate course was from Fromm in 1956, describing Mount Mercy's College senior chemistry seminar course. The course implemented a lab session where students worked on publishable research that was led by faculty.[2] Since then, the growth of CUREs in many institutions has increased due to research being published on the impact and effectiveness of learning caused by CUREs. The *Journal of Chemical Education* consistently publishes examples of CUREs and discusses the efficacy in supporting student retention and learning.[3] For example, there were at least 38 published CUREs between 2010 and 2020.[4]

While undergraduate research experiences, usually in the form of a research internship with an advisor, is a traditional path that future scientists take, most STEM students do not get a chance to explore research opportunities at a university due to limited time and availability of research advisors. CUREs offer research opportunities to a larger number and more diverse group of students, including students who normally would not be able to commit the time and effort to a research advisor's research group outside of class or do not have the experience needed to join the research group. Having a CURE-style chemistry laboratory course offered at an introductory level creates the opportunity to have more students learn about the fundamentals of research, which may not be known to them. Exploring research in just a quarter or semester could change a student's outlook on potentially joining a research group or pursuing a research internship leading to even more scientific opportunities.[2] Integrating authentic research into a laboratory curriculum increases the experimental learning in students.[1] Traditional laboratory curricula have strict procedures to follow with predictable and known outcomes based on well-known science concepts. Research-based learning allows students to make their own decisions regarding modifications to their project or experiment, as well as discuss how to collect and analyze their data, communicate findings, and troubleshoot errors or issues when they arise with these unknown results or conclusions.[2]

Five Dimensions of a CURE

There are five main dimensions of a CURE, also known as the laboratory learning concepts. These can be seen in table 1 in comparison to a traditional laboratory course and the research internship style of laboratory found in research groups.

Table 1. Dimensions of laboratory learning concepts for a traditional laboratory course, a CURE course, and the research internship.[1]

Dimension	**Traditional Laboratory Course**	**CURE Course**	**Research Internship**
Use of Scientific Practices	Few scientific practices, instructor driven	Multiple scientific practices, instructor or student driven	Multiple scientific practices, instructor or student driven
Discovery	Instructor defined purpose, outcome is known to students and instructors.	Student or instructor defined purpose, outcome is unknown	Student or instructor defined purpose, outcome is unknown
Involvement in relevant work	Limited relevance	Extends beyond the course	Extends beyond the course
Collaboration	Occurs among students	Occurs among students, teaching assistants, and instructors.	Occurs among students, teaching assistants, and instructors.
Iteration	Not typically built into course	Often	Often

First, the students should use scientific practices that are involved in science research.[1] Within this emphasis on scientific practice, there are three phases: development of a hypothesis, collecting and analyzing data, and communicating findings.[4] This also includes activities such as asking questions, building and evaluating models, designing studies, selecting methods, troubleshooting with experimental and data analysis problems, and developing interpretations.[1]

Second, students should be involved in discovery. New insights and/or knowledge are obtained and used to further our understanding of science. The outcome of the investigation done in the CURE is not known to the students or the instructors at the outset of the project. Without knowing the outcome of the experiment, the students must make decisions as to how to troubleshoot if an issue arises, how to interpret the data, and how to make conclusions from their results. A part of discovery also contains the risk of uncertain or unanticipated results because the work being researched has not been done before. Evidence-based reasoning and exploration are also part of the discovery process. Some knowledge must be known about the topic of the CURE, and the instructor should have experience in the background science. This is needed so that students can determine whether new evidence that is found is sufficient to support the claim that new knowledge has been produced. This leads to the testing and creating of new hypotheses, which is a core part of the discovery context of a CURE.

Third, students need to be involved in relevant or important work. Contributing to current scientific knowledge is an opportunity of a CURE. The ability to have an impact beyond the classroom increases students' interest in the class so this should also drive the CURE. In higher level courses of CUREs such as physical chemistry, this could be seen in authorship of publications based on the work performed in the CURE. An example of an upper-level CURE in biochemistry is Enzyme Immobilization on Solid Substrates to Enhance Biocatalytic Activity.[4] Reports on water quality in the students' communities are another example of how students are involved in relevant or important work in a CURE.

Fourth, students should be involved in collaboration. Multiple scientists can approach complex problems as many groups with many different resources. Group work is beneficial in a CURE due to the bringing together of multiple minds to confront a problem. The students can improve their quality of work due to peer feedback, as well as help develop intellectual and communication skills when discussing their thinking and interpretations with other students.[1]

Lastly, CUREs involve introducing students to working in iteration. In science, research is iterative because new knowledge builds on existing knowledge. The repetition of studies and experiments is how theories are developed due to the accumulation of evidence over multiple trials and approaches. Students in CUREs will generally design, conduct, and interpret their results from analyses followed by repeating and revising their design of the experiment to adapt to problems or inconsistencies. Students could also build on or revise other students' investigations from previous or related research. They could also be testing a preliminary hypothesis to increase confidence and validity of previous findings. The learning aspect of a CURE comes from failure–trying, failing, trying again, revising, trying again, and evaluating their work as to whether the claims can be supported by evidence.[1]

CUREs at DePaul

CUREs in the chemistry department at DePaul have not been implemented before this research project. Therefore, a pilot program was created to run a CURE in a general chemistry laboratory section, and to study the outcomes from the CURE compared to a standard lab section. A CURE in the general chemistry sequence gives the opportunity for students early on in their college careers to run a research-style experiment where the outcome is unknown and let them troubleshoot and explore ideas surrounding the research. From this experience of working on a scientific research project, these students can choose to pursue a spot in a research group at DePaul or potential internships that require research experiences. They can learn the ability to take ownership of their work and how to follow a procedure that could require adaptation or troubleshooting if something needs to be changed or fixed. A CURE exposes multiple students at once to authentic scientific research instead of a small number of students who are able to join a research team as an undergraduate. As more students are exposed to research, more will hopefully take an interest in innovative development and will want to stay involved in scientific research.

Students at DePaul usually get involved in research through volunteering, research for the Junior Year Experiential Learning credit (CHE 397), and through paid positions funded by the Undergraduate Research Assistant Program or Undergraduate Summer Research Program. While the CHE 397 course does give credits to students, it is one student at a time and is not built into a course required for the student to take as it was done in the General Chemistry Course.

In addition to creating a CURE for the General Chemistry, we were also interested in assessing the research abilities of the students involved in the CURE. When analyzing the CURE developed for the students, many published surveys were examined as to how they could help determine the use and validity of usage of the CUREs. With the five dimensions of a CURE in mind--use of science practices, discovery, broader relevance or importance, collaboration, and iteration—the surveys we decided on were the Meaningful Learning in the Laboratory Instrument (MLLI) and the Experimental Design Ability Test (EDAT).[5,6]

Theoretical framework

The theoretical framework used in this research was Constructivism. Constructivism focuses on individuals making sense of their experiences.[7] Its foundation is in the cognitive sciences, which is the study of thought, learning, intelligence, and mental organization.[8] This framework follows the assumption that we do not discover existing knowledge, we actively construct it. It also assumes we invent concepts and models to make sense of our experiences and then repeatedly test and modify these constructions in light of new experiences.[7] Constructivism supplies a basis for understanding how people integrate new knowledge into existing knowledge and then make sense of this knowledge.[7] As constructivism is built around constructing new knowledge, pedagogy should be built around enabling people to construct this knowledge. The experiences that students need are in the cognitive, affective, or psychomotor domains.[9] The cognitive domain refers to concepts and reasoning skills, the affective domain refers to attitudes and motivations, and the psychomotor domain refers to action/dexterity and precision. All three of these experiences are needed in order for meaningful learning to occur in the student.[9] This aligns with both the MLLI survey framework and the EDAT framework. The MLLI survey has items classified as either cognitive, affective, or both cognitive and affective in nature. The EDAT uses the scoring rubric as a guide through the students' thought process of the design of an experiment.

<u>Assessing CUREs</u>

Several assessments exist to examine students' learning and affect during research. One example of a survey explored was the Project Ownership Survey, POS.[10] This survey incorporates personal responsibility with commitment to and recognition of the work completed in the course.[10] Project ownership is an important topic to consider since it is directly tied to the research project and the educational experience of the student.[10] This survey is limiting as it would only be given to the CURE students since the items on the survey all pertain to the research project. The non-CURE students do not have a particular project at hand, so giving this to both courses to compare would not be feasible. The CURE survey and the Survey of Undergraduate Research Experiences (SURE) developed by Grinnell College was also explored due to its use in measuring students' experiences in CUREs and research experiences.[11] These were both ultimately not used due to the survey having demographic questions and level of experience questions which were not the aim of the assessment.

The MLLI is an assessment tool that was explored and chosen due to its aim to measure the students' expectations before and after the laboratory course through the perspective of conducting experiments in the course.[5] This assessment looks at both the cognitive and affective domains. This tool uses Joseph Novak's Theory of Meaningful Learning and Human Constructivism, which states "Meaningful learning underlies the constructive integration of thinking, feeling, and acting leading to human empowerment for commitment and responsibility."[5] In a teaching laboratory, how a student chooses to act (psychomotor) in the lab depends on how they think about (cognitive) and feel (affective) toward their laboratory experiences. Performing a laboratory experiment requires the scientist to "do science", therefore the question at hand is how students integrate their thoughts and attitudes with the action, which is assessed with MLLI.

The EDAT was also used to survey the students.[6] This survey consists of a two varying prompts for pre- and post-delivery regarding an everyday science problem about which the students must write an open-ended response. This helped measure the students' general understanding of experimental design and their ability to design specific experiments. In the prompt, students must explain how they would accept a claim about a specific commercial product. They first need to recognize that an experiment can be done to provide evidence that the claim is reasonable. The EDAT is open-ended format and independent, so the students write and guide the reader through the thought process of the design of the experiment. The provided experimental design should have control variables, independent and dependent variables, sample sizes, reproducibility, limitations, timeline, and other factors needed in an experiment. The EDAT provides more insight into the thought process of a student, which is why it was chosen for the CURE assessment. It is content independent requiring no previous knowledge to the topic in the prompt but makes the student think through designing an experiment--a skill that was used throughout the CURE to some extent--but in their own mindset without any guidance like they received during the CURE.

The EDAT was chosen as an assessment tool because it did not require a lot of time to administer, was based on a practical challenge, did not require many quantitative skills from students, was open-ended to elicit students' thinking, was able to be scored consistently across students, and provided a quantitative measure.

Chapter 2 will discuss the experimental methods used in more detail as well as the structure of the CURE and non-CURE course sections. Chapter 3 will discuss the MLLI and EDAT results. Chapter 4 will discuss conclusions and future work.

Chapter 2: Methods

The objective of this research was to incorporate CUREs into DePaul's General Chemistry III Laboratory course (CHE 135). Before running the CURE, brainstorming possible laboratory experiments to conduct that could have modifications made by students and also related to the curriculum's objectives and learning outcomes was discussed. The research progress balancing with the student learning and development was also discussed. Assessment of progress was also discussed since unpredictable outcomes including failed trials or no collectible data were inevitable. This led to the use of an electrochemistry experiment being implemented into the course with a proper timeline for proposals, troubleshooting, and presentation of findings.

In a standard CHE135 laboratory section, 8 experiments were conducted over the ten-week quarter for General Chemistry III laboratory with weeks 1 and 10 having no lab. Of the eight experiments, five required a lab report due the following week and the other three experiments had worksheets to be completed. These experiments are shown in table 2 and covered acids and bases, buffer solutions, titration of an unknown amino acid, Le Chatelier's principle, spectrophotometric analysis of manganese in steel, thermodynamics of a complexation reaction, electrochemistry, and synthetic coordination chemistry.

In the CURE laboratory section, the schedule for the ten-week quarter differed from the standard laboratory section, as seen in table 2. Two of the standard experiments were conducted during the CURE laboratory section, specifically covering acids and bases and Le Chatelier's principle. The pre-surveys were given in week 1, when no lab was being conducted and the post-surveys were given in week 10 for the CURE section when presenting their results and week 9 for the non-CURE section after the final laboratory experiment was completed. All interactions with the students followed the approved IRB application.

Table 2. Weekly Schedule of Non-CURE and CURE course

Week Number	CURE Course	Non-CURE Course
1	Survey Assessment	Survey Assessment
2	Experiment 1: Acids and Bases	Experiment 1: Acids and Bases
3	Run Electrochemistry Experiment from paper	Experiment 2: Buffer Solutions
4	Continue running Electrochemistry Experiment, test out modification ideas (initial proposal)	Experiment 3: Amino Acid Titrations
5	Experiment 4: Le Chatlier's Principle + Written proposal due	Experiment 4: Le Chatlier's Principle
6	Run Modification 1	Experiment 5: Spectrophotometric Analysis of Manganese in Steel
7	Run Modification 2	Experiment 6: Thermodynamics of a Cobalt Complex
8	Troubleshooting	Experiment 7: Electrochemistry
9	Final data collection, Start work on lab and poster	Experiment 8: Coordination Chemistry + Survey Assessment
10	Draft Lab and Poster Due Survey Assessment	

To prepare for the electrochemistry experiment that the students would later modify for their own projects, the students had to read the *Journal of Chemical* Education article that the project was based off of and watch a related video from this article's supplemental material.[12] Students also had to complete a quiz regarding this paper to show understanding of this material. They were introduced to the material in week 2 before the acids and bases experiment was performed as well as given a review lecture about redox chemistry, buffers, and carbon monoxide safety. The journal article the students read discussed an experiment on electrochemical reduction of CO_2 to CO using readily available materials such as batteries, copper and nickel wire, plastic bottles, and a handheld carbon monoxide detector.[12] The assembly of the divided electrochemical cell is discussed in the paper and pictures of the apparatus assembly are shown in figure 1. Once students had a working apparatus, they could carry out electrolysis. In weeks three and four, the electrochemical cell setup was created, and both the electrolysis of water and bicarbonate and CO_2 reduction were run. The results of both parts were compared in the amount of CO produced. The initial electrochemistry experiment had two parts. The first was the electrolysis of water and bicarbonate. This used 0.5 M $KHCO_3$ as the electrolyte solution, copper wire for the cathode, nickel wire for the anode, and a 9-volt battery for the power source. CO production was measured using the CO detector over 10 minutes. The second part of the electrochemistry experiment was CO_2 reduction. The same parameters were used as before, but CO_2 was bubbled into the electrolyte prior to electrolysis. The CO production was again measured using the CO detector over 10 minutes. The lab handout found in appendix A was given to the students for preparation for both parts.

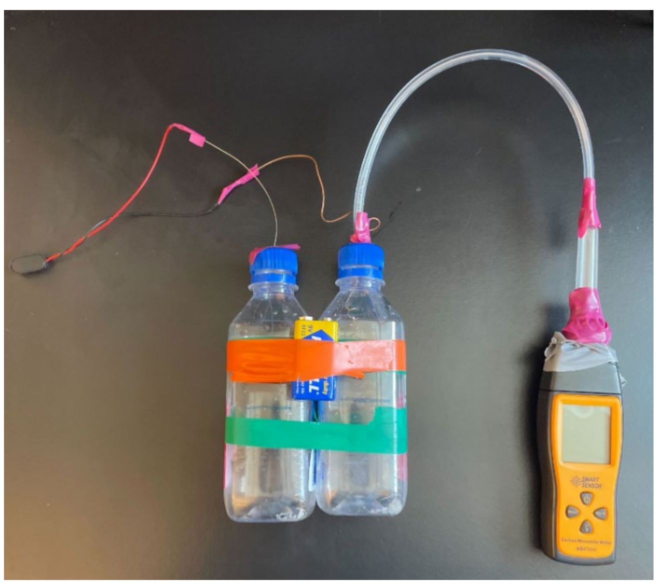

Figure 1. Materials shown are those used in the CURE, for the construction of the DIY electrochemical cell for CO_2 electrolysis or water splitting.

After the students collected CO from the electrolysis of water and bicarbonate and the electrolysis of CO_2, they had to propose a modification they would make to the setup for their own project. These modifications varied from changing the pH of the electrolyte solution to changing the metal cathode; all of the student modifications are shown in table 3. In pairs, students had to determine possible challenges for their proposed experiment, as well as identify a control experiment to be used in their project. Examples were provided such as changing the electrolyte cation with two different concentrations or changing the surface area of a different electrode with two different submerged depths to compare to copper. Any relevant half reactions that could have been occurring at each electrode were also listed to explain the observations.

Table 3. Modifications completed in the CURE.

Group Number	Modification
1	Copper to Iron cathode wire with two thicknesses: 0.5 mm and 1.0 mm
2	pH of electrolyte solution changed to more basic using potassium hydroxide
3	Copper to zinc cathode Copper to silver cathode
4	Copper to carbon cathode Copper to gold nanoparticles cathode
5	Potassium bicarbonate electrolyte solution to Lithium bicarbonate solution with two different concentrations: 0.1 M and 0.05 M
6	Copper to Iron cathode Copper to Iron wool cathode (increasing surface area)
7	Decreasing pH of potassium bicarbonate electrolyte solution by addition of HCl at two concentrations: 0.25 M and 0.5 M
8	Varying CO_2 bubbling time: 2 minutes, 4 minutes, and 6 minutes
9	Varying pH of potassium bicarbonate electrolyte solution by adding HNO_3 or HCl
10	Copper to Zinc cathode Decreasing pH of potassium bicarbonate electrolyte solution by addition of HCl

During week 5, the Le Chatelier's principle experiment was conducted but discussion of the modifications were done with each group during that lab to ensure that the students were providing modifications that could be completed. The last four weeks of the quarter were devoted to the students' projects to ensure proper time for troubleshooting and data collection. A final lab report and poster were the final assessments of the quarter. Students were given instruction on scientific posters, as well as a template to use, although they were also allowed freedom to use their own poster designs. On the final day of class, students gave a 2 to 5-minute talk on their overall experimental modification and main results to the class. They were also given the post-survey to complete in the same manner the standard laboratory section did.

Upon completion of the quarter, both the CURE and non-CURE courses' pre- and post-surveys were assessed and deidentified. The EDAT was scored using a rubric with scores of 1 to 10 based on ten criteria to assess the experimental design. The MLLI results were recorded and compared using their difference between pre- and post-overall score. Results of both surveys are discussed in Chapter 3.

Chapter 3: Results and Discussion

The results were obtained with the EDAT to measure the students' ability to design an experiment and with the MLLI to measure the students' cognitive and affective expectations and experiences in the course.[2]

MLLI Results

When administering the MLLI to the students, they were asked to score each item on a scale of 0 to 10 based on their expectation (pre-survey) and experience (post-survey) for the course. The MLLI survey can be seen in appendix B1. When analyzing the MLLI results, the negatively worded items, thirteen of the 31, were reverse scored to properly portray the answer to the item. After properly recording the results, the answers from the post-survey were compared to the pre-survey results. This is done by adding the total from all 31 items and obtaining a difference between the pre- and post-surveys. This number can be seen as a positive gain, with a larger value implying a larger increase in student learning, a net gain of 0 with no change between the pre- and post-survey scores, or a negative value meaning they scored lower on the post- versus the pre-survey. This is shown in figure 2 for the non-CURE section and figure 3 for the CURE section. Table 4 shows the averages of the pre- and post-survey overall scores as well as the averages of the calculated differences between the post- and pre-surveys including standard deviations of the calculated differences.

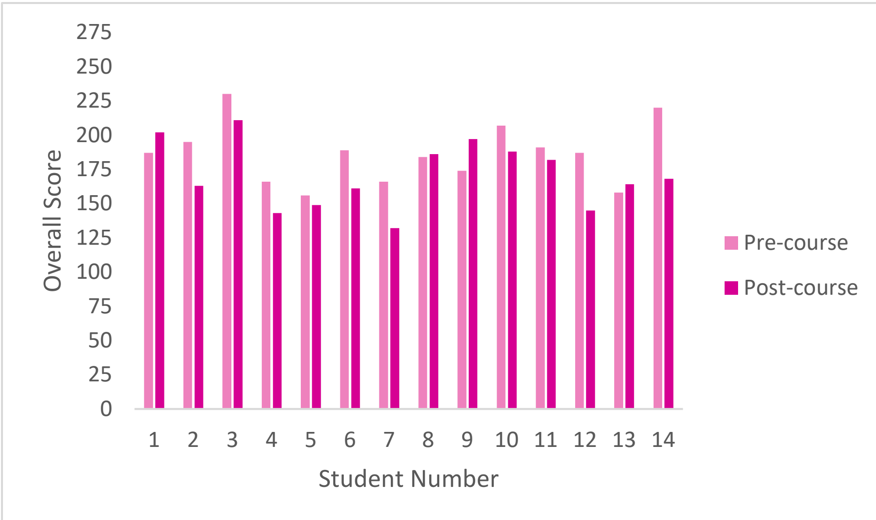

Figure 2. Non-CURE MLLI results for pre- and post-course by student

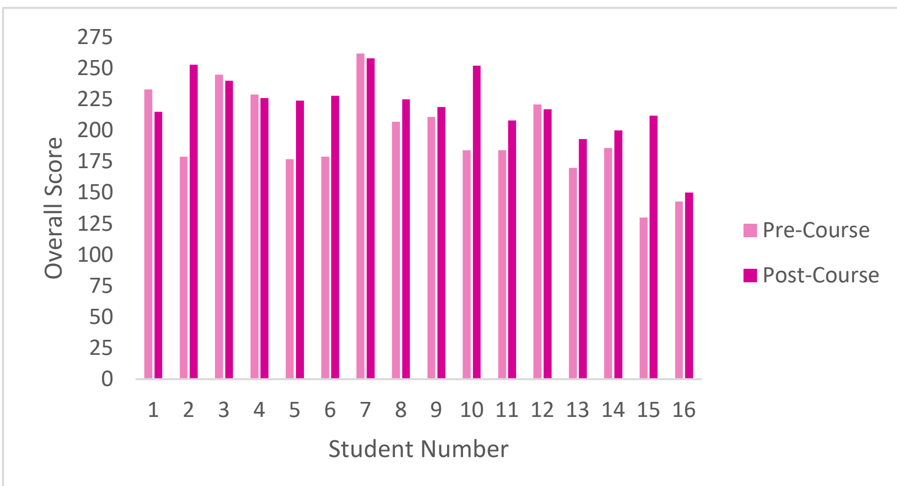

Figure 3. CURE MLLI results for pre- and post-course by student.

Table 4. Averages and standard deviations for the CURE and non-CURE MLLI results for pre and post course

Data Calculated	Non-CURE Results	CURE Results
pre-survey average	186 ± 22	196 ± 36
post-survey average	171 ± 24	220 ± 26
difference average	-16 ± 22	24 ± 31

To compare the results, the difference between the post- and pre-surveys were calculated. In the non-CURE section, there was a negative overall score for 10 of the 14 surveys collected (71%). In the CURE section, there was a negative result in only 5 of the 16 collected (31%). While analyzing the results of the survey, it was observed that many students decreased in many of the negatively worded questions in both the pre- and post-survey. Specifically, this was seen more so in the non-CURE results. This could be due to students misreading or scoring themselves in the opposite manner, which is hard to determine. At 98% confidence according to a two-tailed distribution paired t-test (DOF =13, p = 0.05), there is no statistically significant difference between the pre-course surveys and the post course surveys in either the CURE of non-CURE course.

Another way to analyze the MLLI data is to separately analyze the affective versus cognitive domain questions. The survey questions with domain type are shown in appendix B1 for each item. There were 8 items in the survey that were related to the affective domain, which were based around the students' feelings and attitudes toward the course. For example, one affective item to be scored by the student is "to develop confidence in the laboratory".[11] There were 16 items in the survey that were related to the cognitive domain which are based around the students' conceptual thinking and reasoning skills. An example of a cognitive item that students scored is "to consider if the data makes sense."[11] There were also 6 items in the survey that were related to both cognitive and affective domains meaning both their attitudes and reasoning skills were involved when answering the item. An item from the survey that students scored that states, “to learn chemistry that will be useful in their life” is an example of both cognitive and affective domains.[11]

When analyzing the cognitive and affective domain items, both the non-CURE and CURE sections showed a larger number of surveys with a negative gain from pre- to post-survey in cognitive domain items. The non-CURE section showed 10 negatively gained in the cognitive and 6 in the affective while the CURE showed 6 negatively gained in the cognitive and 2 in the affective. Specifically for the cognitive domain items, 10 out of 14 students (71%) with negative gains were seen in the non-CURE section whereas there were only 6 out 16 students (38%) in the CURE section. When looking at positive gain in the cognitive domain, the non-CURE section had 4 out of 14 students (29%) and the CURE section had 10 out of 16 (62.5%) students. More students in the CURE section showed a higher gain in the cognitive items than the non-CURE section, and higher gains overall were observed for the CURE section compared to the non-CURE section. For example, the highest two gains in the CURE were 29 and 20 while the highest two gains for the non-CURE were 9 and 5. These results of the cognitive domain items for the non-CURE section are seen in figure 4 and the CURE section in figure 5. Table 5 shows the affective domain averages of the pre- and post-survey overall scores as well as the averages of the calculated differences between the post- and pre-surveys including standard deviations of the calculated differences.

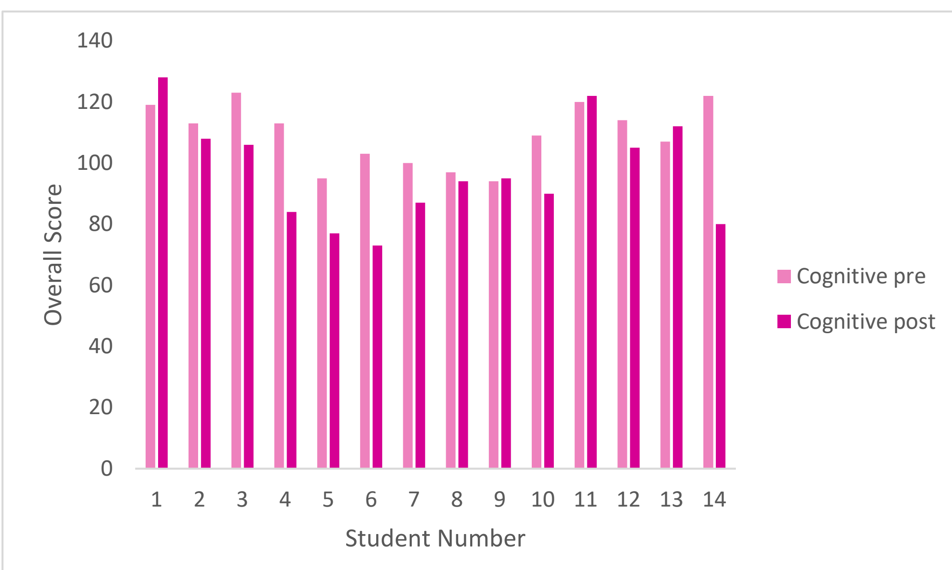

Figure 4. Non-CURE course scores of pre- and post-surveys for cognitive domain items.

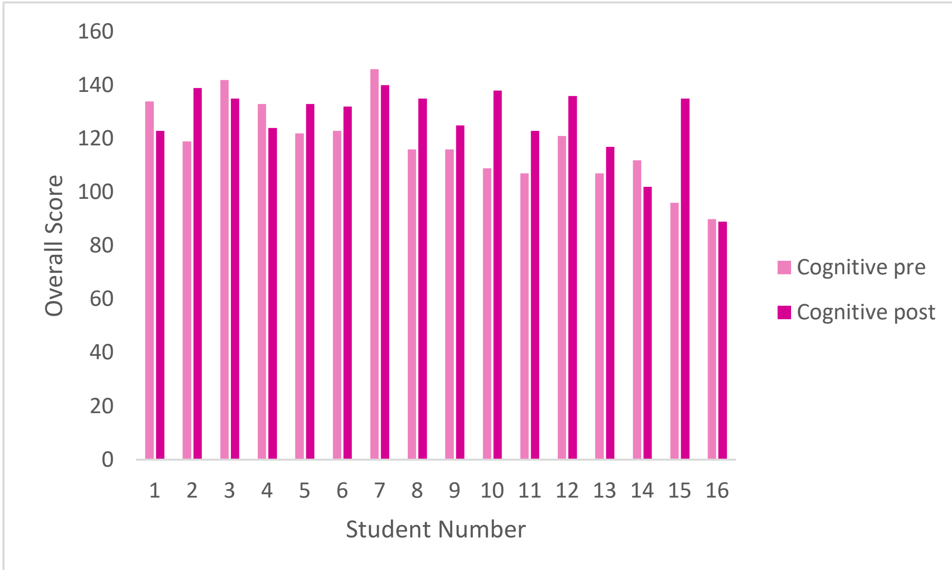

Figure 5. CURE course scores of pre- and post- surveys for cognitive domain items.

Table 5. Averages and standard deviations for the CURE and non-CURE MLLI cognitive domain results for pre- and post-course.

Data Calculated	Non-CURE Results	CURE Results
pre-survey average	109 ± 12	118 ± 15
post-survey average	97 ± 12	127 ± 14
difference average	-12 ± 12	8 ± 14

In regards to the affective domain items, 6 out of 14 students (43 %) with negative gains were seen in the non-CURE section whereas there were only 2 out of 16 students (12.5 %) in the CURE section. In terms of positive gain of the affective domain items, 7 out of 14 students (50%) in the non-CURE section were seen while 12 out of 16 (75%) were seen in the CURE section. Following the same trend of the cognitive domain items, more students in the CURE section showed a higher gain in the affective items than the non-CURE section. Higher gains overall were again observed for the CURE section compared to the non-CURE section in the affective domain items. Specifically, the highest two gains in the CURE were 29 and 25 while the highest two gains for the non-CURE were 18 and 8. The results of the affective domain items for the non-CURE section are seen in figure 6 and the CURE section in figure 7. Table 6 shows the affective domain averages of the pre- and post-survey overall scores as well as the averages of the calculated differences between the post- and pre-surveys including standard deviations of the calculated differences.

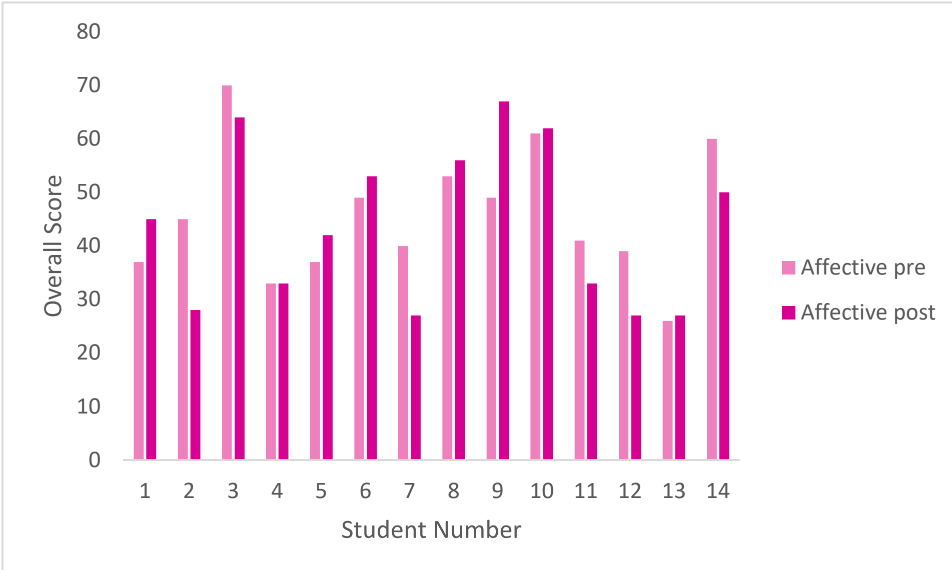

Figure 6. Non-CURE course scores of pre- and post-surveys for affective domain items.

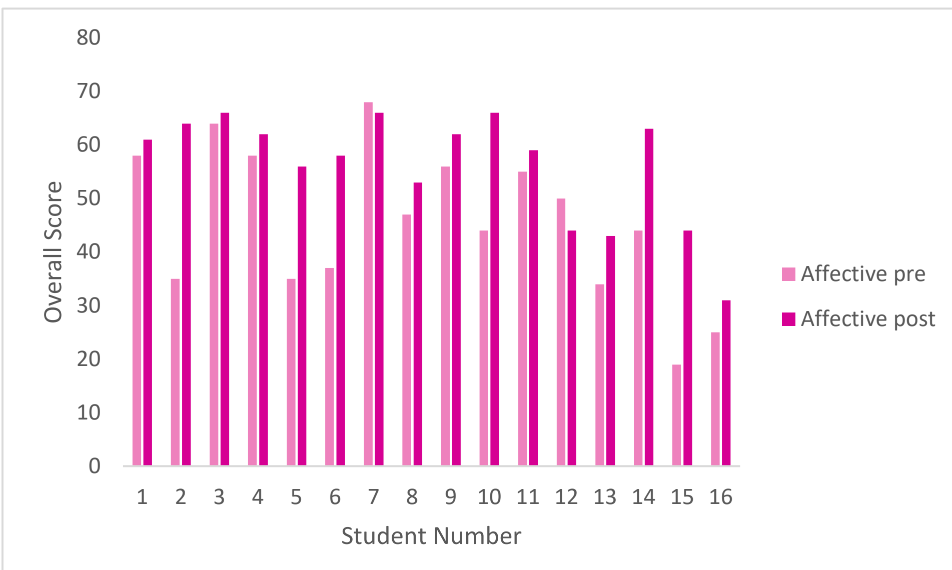

Figure 7. CURE course scores of pre- and post-surveys for affective domain items.

Table 6. Averages and standard deviations for the CURE and non-CURE MLLI affective domain results for pre- and post-course.

Data Calculated	Non-CURE Results	CURE Results
pre-survey average	46 ± 12	46 ± 14
post-survey average	44 ± 15	56 ± 10
difference average	-2 ± 10	11 ± 11

Looking at the cognitive and affective combined items, the non-CURE section showed 7 out of 14 students (50%) with negatively gains while the CURE section showed 4 out of 16 (25%). These results of the cognitive and affective combined items are seen in figure 8 for the non-CURE section and figure 9 for the CURE section. Table 7 shows the cognitive/affective domain averages of the pre- and post-survey overall scores as well as the averages of the calculated differences between the post- and pre-surveys including standard deviations of the calculated differences. All of the MLLI gains can be seen through the raw data tables found in Appendix C1.

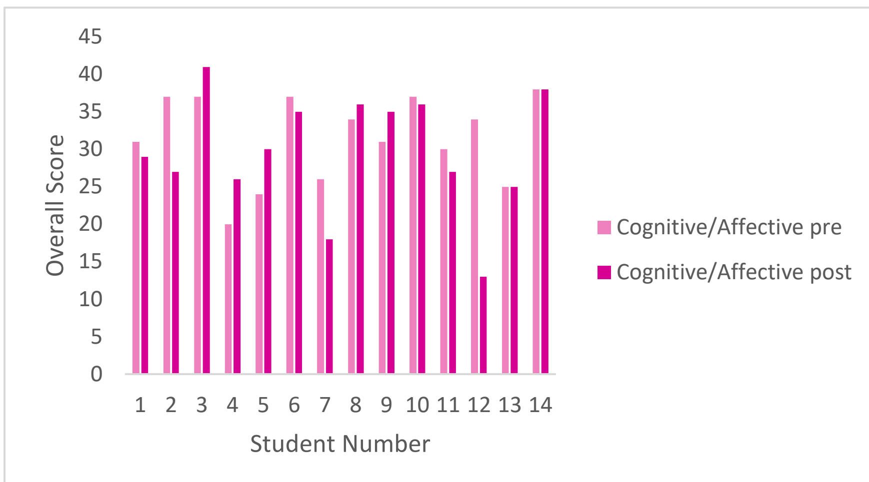

Figure 8. Non-CURE course scores of pre- and post-surveys for cognitive/affective domain items.

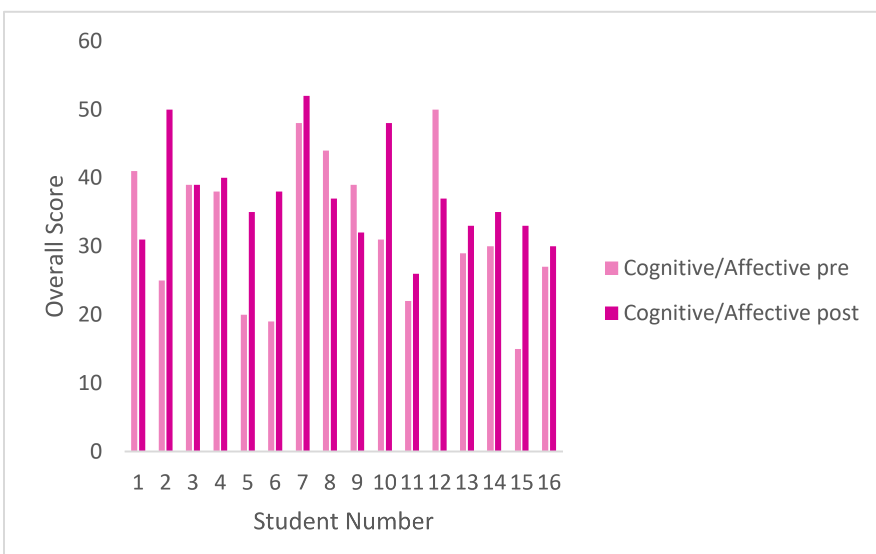

Figure 9. CURE course scores of pre- and post-surveys for cognitive/affective domain items.

Table 7. Averages and standard deviations for the CURE and non-CURE MLLI cognitive/affective domain results for pre- and post-course.

Data Calculated	Non-CURE Results	CURE Results
pre-survey average	32 ± 12	32 ± 11
post-survey average	30 ± 12	37 ± 7
difference average	-2 ± 12	5 ± 11

These results ultimately show that the affective domain items were more positively affected items in the surveys for both formats with the CURE course having higher than non-CURE course. According to a two-tailed distribution paired t-test (DOF =13, p = 0.05), there is no statistically significant difference between the two groups when looking at the cognitive, affective, and cognitive/affective domain items. A larger sample size may lead to statistical differences. Anecdotally, a student used the CURE course during a research internship interview to talk about positive experiences they had with research. This student was accepted to the internship and did speak of enjoying the course. A professor also reported that three students who went on to a research program called "Rising STEM Scholars" spoke highly of the experience as well. This is anecdotal evidence of positive outcomes in the affective domain.

<u>EDAT Results</u>

The EDAT results for both pre-and post-prompts (Appendix B2) were obtained based on ten criteria shown in the rubric in Appendix B3. There is a maximum score of 10, 1 for each criterion. In the rubric, the criteria are listed in a manner of increasing difficulty for students to include in their response. This means the tenth point is the hardest to earn versus the easiest point being the first criterion. These EDAT results are shown in figure 10 for the non-CURE course and figure 11 for the CURE course.

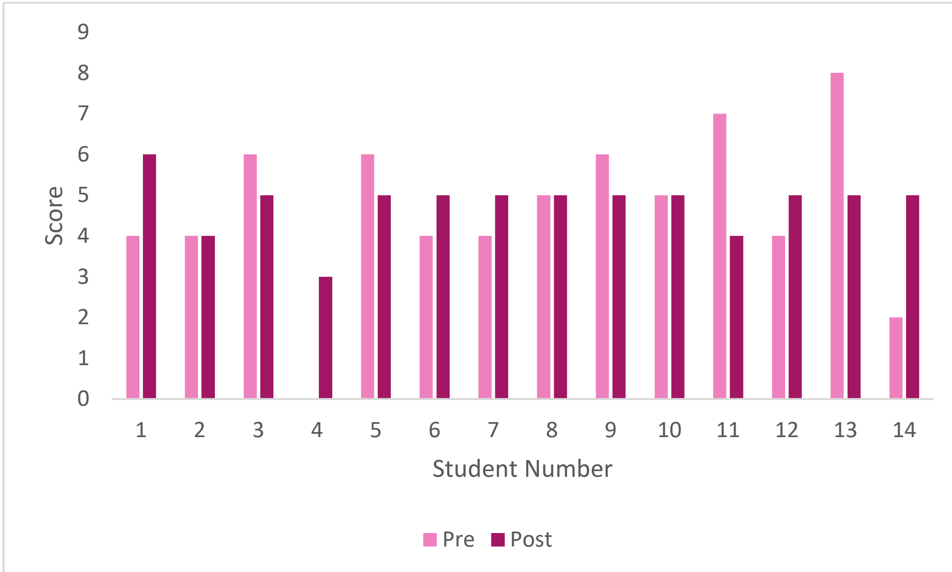

Figure 10. Non-CURE EDAT results by student for pre- and post-survey.

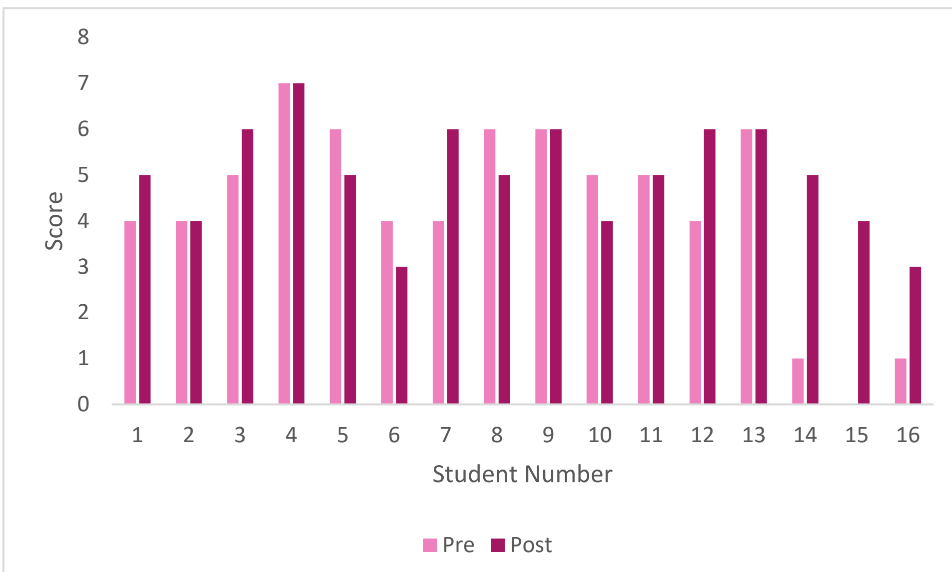

Figure 11. CURE EDAT results by student for pre- and post-survey.

Analyzing the EDAT scores showed that there were 4 out of 14 students (29%) that had a decrease in their score from pre- to post-survey in the non-CURE section and 4 out of 16 students (25%) in the CURE section. The results also showed a highest score increase to be 3 in the non-CURE section and 4 in the CURE section. The non-CURE section showed a score increase in 7 out of 14 students (50%) and 7 out of 16 students (44%) in the CURE section. According to a two-tailed distribution paired t-test (DOF =13, p =

0.05), provided only 22% confidence regarding the statistical difference between the pre- and post-course data. These results are not substantial enough to show a difference between course types. The results obtained can be seen more closely in the raw data in Appendix C2.

Looking more closely into each individual question from the results scored per criterion seems useful in the difficulty aspect of the EDAT. These results are shown in tables 8 and 9 based on the criteria increasing in difficulty.

Table 8. Non-CURE EDAT scores in increasing order of difficulty of each criterion pre- and post-course.

Number of students who answered the criteria	Pre-Course	Post-Course	Difference
1. recognition that experiment can be done	13	14	1
2. recognition of independent variable	12	14	2
3. recognition of dependent variable	12	13	1
4. recognition of how dependent variable measured	10	10	0
5. recognition of one variable held constant	4	2	-2
6. recognition of placebo effect	4	8	4
7. recognition of many variables that are held constant	2	0	-2
8. recognition of larger same size meaning better data	5	6	1
9. recognition that the experiment needs to be repeated	3	0	-3
10. recognition of error, limits, and/or can never prove hypothesis	0	0	0

Table 9. CURE EDAT scores for each criterion pre- and post-course.

Number of students who answered the criteria	Pre-Course	Post-Course	Difference
recognition that experiment can be done	15	16	1
recognition of independent variable	13	16	3
recognition of dependent variable	13	15	2
recognition of how dependent variable measured	11	11	0
recognition of one variable held constant	3	3	0
6. recognition of placebo effect	6	8	2

7. recognition of many variables that are held constant	1	1	0
8. recognition of larger same size meaning better data	2	5	3
9. recognition that the experiment needs to be repeated	4	5	1
10. recognition of error, limits, and/or can never prove hypothesis	0	0	0

From tables 8 and 9, only the non-CURE section showed negative gain, seen in 3 students. There can be seen more gain in the CURE students in harder criteria than in non-CURE students, with gain being seen in criterion 8 in 3 students and criterion 9 for 1 student for the CURE section and gain in criterion 8 for 1 student in the non-CURE section. These results show the gain seen in the CURE section that might not be noticeable from the scores seen in figures 10 and 11 alone.

The takeaway from the results show that there is still a gain seen in both the MLLI and EDAT results for the CURE section versus the non-CURE section, despite the average values not being statistically different with only 22% confidence. Students seem to learn more of both the fundamentals of experimental design as well as the more advanced topics in a CURE format. They also seem to show much more affective learning with an increase in interest and positive attitudes as well as cognitive learning with better reasoning skills in comparison to a non-CURE style laboratory course.

Chapter 4: Conclusions and Future Work

Ideally, all students in STEM should get the opportunity to have research experiences while in their undergraduate program. Research under the guidance of an advisor in a research lab is the traditional path, which is only available to a certain number of students with very limited availability, and students can only get course credit for research at DePaul after they have junior status by course credit. CUREs help make these research opportunities become more available to many more students, including students that may not have thought research was a path they wanted to explore. The time commitment for a CURE is only a quarter or semester, whereas working with a research advisor could require much more time from the student. A CURE offered during General Chemistry also provides this research opportunity sooner than most students could typically get with a research advisor or internship. For example, for the DePaul General Chemistry CURE, the only previous experience the students need is to complete the first two quarters of General Chemistry lab and lecture; this makes research much more readily available to students.

Research-based learning allows students to make their own decisions involving their modifications to a project or experiment as well as discuss how to collect and analyze their data, communicate findings, and troubleshoot when errors or issues arise with these unknown results/conclusions.[3] As seen in the MLLI survey results, experimental learning was increased in the CURE section students. This knowledge is needed for STEM students to become successful scientists. Looking at the domain of the items in the MLLI showed a higher increase in both affective and cognitive for CURE students in comparison to non-CURE students. The affective domain showed a higher increase than the cognitive domain which refers to their attitude and feelings with respect to chemistry. An increase in the motivation to conduct research in chemistry is desirable in students who want to pursue a career in experimental science.

Looking at the EDAT results showed that there was a larger gain in the harder criteria from the rubric for the CURE students rather versus the non-CURE students. The non-CURE section also showed a lower score in some students' post-survey that the CURE section did not show. The EDAT survey showed that there is importance to be placed on the students' understanding in experimental design. Specifically, some of the more difficult criteria from the EDAT rubric such as the need for repeat trials, limitations, and errors are of significance for students when conducting an experiment.

There are some topics that occurred over the quarter that were not measurable through the two surveys but worth noting. Many of the students in the CURE section showed genuine interest in the experiment and trials run. For the first time in my teaching experience, students wanted to stay until the end of lab to run additional trials. This particular CURE section ran from 6 to 9 P.M., so students already had a long day. But some students wanted to stay late in order to have a "good" collection for the day, a fixed apparatus for the following week, or simply another trial of data. The desire to complete the experiment and have data that are usable is a scientific mindset that is not usually shown in General Chemistry students. From my experience, students in the traditional format usually have a goal of getting out of the lab as quick as possible with usually very little recognition of what was completed or done in the day. These CURE students all took their time to make sure their data made sense, were usable, and were repeatable. Again, this is what true researchers aim to achieve. Other students also spoke of wanting to pursue research with an advisor after this course. Maybe this was not originally on their path but now, after getting this exploration, they want to keep learning more through research. Another student applied to a research internship over the summer and said that during their interview, they discussed the CURE project, which they felt made them stand out during the interview. Again, these things are not measurable with EDAT and MLLI, but upon discussion with the students, they truly gained and enjoyed these experiences they had in the CURE course. Future assessment methods could involve the use of interviews with the students to get more information from them regarding their feelings after the course.

Looking forward, future assessments should follow students into their following coursework to see what path they end up taking and if they end up doing more research in the future. Although a lot of variables go into the path students will take in STEM, it could be interesting to track if any of the CURE students go into research versus the non-CURE students. Another factor that should be tracked is the grade the students obtain in the course as well as their GPA in future science courses. Following their path through their undergraduate program could be helpful. This would also help get a better idea if there truly is a gain in research skills throughout the student's path at school. An additional factor to consider is obtaining more survey results. Although we collected two classes worth of data, there were only 14 students in the non-CURE and 16 students in the CURE, which affects the generalizability of the data and results. Invalid or incomplete responses led to the number of surveys being less than the students enrolled in the courses. Net gains were observed in some of the students, but observing more students a year would be much more beneficial. This requires more professors willing to run CURE labs. This also leads to the issue that there are only so many General Chemistry III laboratory courses offered. But, if looked at over the course of a few years, the data from the surveys could be analyzed and better discussed with a larger sample size.

Adding an additional survey could be beneficial. We do not want to take up too much time of the students before the course, but the Project Ownership Survey, POS, could be useful for showing if the students gain in their ownership of the project.[11]

With a larger sample size, we could consider topics such as demographics, such as age or race. If demographics were incorporated, the CURE or SURE survey could be used as an assessment tool as well. Another point to consider is how CURE courses could help non-traditional students. As a non-traditional student myself, this could help students explore research if they cannot fit in the research internship experiences between school, work, and/or family. Students who are also parents usually cannot make these internships fit into their schedules, so taking a CURE-formatted course could help them gain research knowledge and experience they would not have been able to get without.

Making research available to a wider range of STEM students at DePaul is a challenge that needs to be addressed, and using CURE formatted laboratory courses could do this in multiple courses, not just chemistry.

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Appendices

Appendix A: CURE Lab Handout

Student Handout for Day 1 of the CURE (April 13th)

Goal for today: create the cell setup and try out electrolysis of just water/electrolyte and compare that with electrolysis of CO_2. Note that things may deviate from the procedure below as we proceed, that's ok, be sure to write down your deviations and what you did!

Safety Considerations

1. Always wear proper attire, safety gloves, and goggles while inside the lab.
2. CO will be produced in this experiment and it is a neurotoxin. However, the amounts produced in this experiment are incredibly low, so no risk of poisoning is present. The work should be performed in a well-ventilated area (ideally, in a fume hood). To check CO levels in the atmosphere outside of the electrochemical cell, another CO detector will be used.
3. H_2 will be produced in this experiment. H_2 is flammable, but the amount of gas produced is negligible, and no risk of explosion is present. Open flames should be avoided.

Experimental Procedures

Setting up H-cell for the experiment

Materials:

- 2 plastic bottles with screw caps (use any flexible plastic bottles, e.g., bottles from water, juice or pop, as long as they are well-rinsed; if bottles with cuboid shape are available, these would be ideal, however, cylindrical bottles that satisfy the above requirements work perfectly fine). For sealing of the cathodic compartment headspace, a rubber septum can be used instead of a screw cap.
- An ion-exchange membrane (e.g., Fumasep FAS-PET-75 from

FuelCellStore.com).

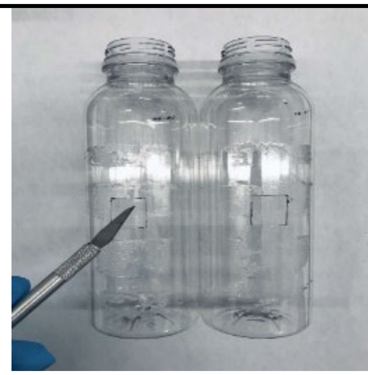
- A hand-held digital CO meter, e.g., ANPIGGY ST9700 or AS8700A available on Amazon.com (alternatively, a standard household CO detector for qualitative analysis only).
- 9V batteries
- Sticky tape (e.g., masking tape or scotch tape), epoxy or super glue
- X-acto knife or scissors.
- Plastic tubing.
- Copper wires.
- Electrolyte solution ($NaHCO_3$)
- To saturate the electrolyte with CO_2, a laboratory CO_2 gas tank equipped with a regulator and a tubing or dry ice can be used.

Part A: Making an H-cell

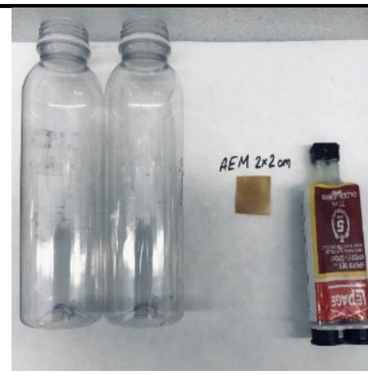
1. Take two plastic bottles of the same size.

2. Draw a 1.5 cm x 1.5 cm square trace for a hole on each bottle.

3. Make holes with an x-acto knife or scissors.



4. Cut a 2 cm x 2 cm (approximate size: it can be smaller or larger, depending on the bottle size; it has to be larger than the opening holes cut in the bottles) square piece of an ion exchange membrane.

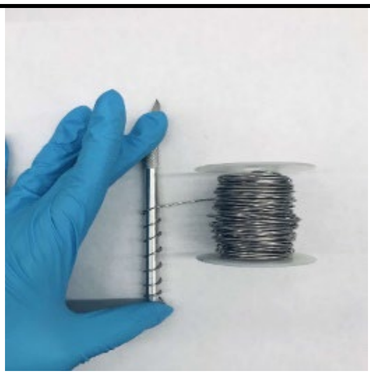


5. Cover the edges of the square hole in a bottle with epoxy or super glue, place the ion exchange membrane to fully cover the hole, press its edges into the glue, and let it dry. Extra epoxy can be used to seal around the edges for textured bottles

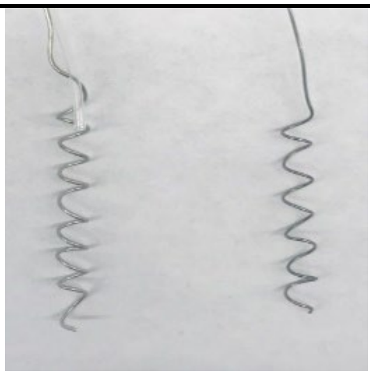
6. Carefully attach the second bottle on the other side of the membrane by using the epoxy or super glue around the perimeter of the second hole. After the setup is dry, fill bottles with water to ensure that there is no leak at the junction. Be gentle with the setup. You can wrap tape around the two bottles to support it.

Part B: Making the electrodes and assembling the H-cell

1. Roll the appropriate metal wire around a pencil to make a spring. Repeat the procedure for your cathode (Cu) and anode (Ni wire). Aim to make the spirals with similar length and pitch. It's a good idea to estimate the surface area of the electrode/how much will be submerged and keep that constant.

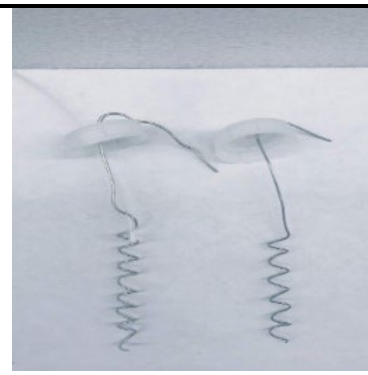


2. Mark the cathode and the anode, feed a plastic tube through the cathode wire spiral for gas analysis (shown on the left).



3. Make one hole in each cap from the bottles to secure the electrodes. The hole on the cathode side needs to be large enough for both the tubing and the wire.

4. Feed the electrodes and the outlet tubing (with the cathode) through the holes.



5. Fix the wires to the lids with epoxy or super glue. The cathode cap should ideally be sealed allowing the gas escape only through the tubing. The anode cap should not be sealed allowing oxygen gas produced during electrolysis to escape.

6. Screw the caps onto the bottles keeping the springs slightly above the bottom of the bottles.

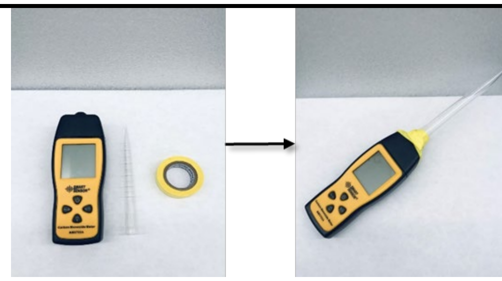
7. Wrap the exposed parts of the wires with insulating tape, such as Teflon tape or electrical tape, to avoid the wires touching and causing battery short circuit when the ends are connected to the battery (Part C). Alternatively, enclose these segments of the wires using insulating plastic hoses.

Part C: Attaching the battery and assembling the detector

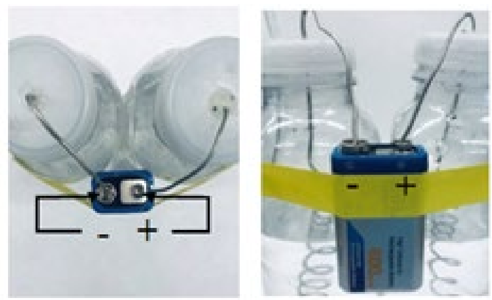
1. Use a tape to attach a 9V battery to the side of the H-cell near the caps with contacts facing up.

2. Attach a plastic pipette tip or a

tube to interface the detector with the outlet tubing of the H-cell for higher accuracy



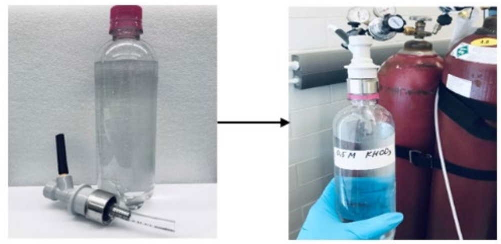
3. When ready to start the reaction (when the electrolytes are inside), connect the cathode to the negative port of the battery and the anode to the positive port, as shown in the figure. It is important to ensure that the two wires connected to the two battery ports never touch (avoid short circuit!). Ensure that there is a sufficient distance between the wires, or better use insulating tapes or hoses (see part B).



4. Attach the outlet from the cathode compartment to the detector (or place it as close to the hole in the cap as possible)

Part D: Experimental setup

Prepare 0.5 M $KHCO_3$ to use as the electrolyte:



1. Make 0.5 M $KHCO_3$ solution and take a pH measurement
2. If doing CO_2 electrolysis, saturate it with CO_2 using a CO_2 carbonator or a soda machine. Bicarbonate solution can be saturated by bubbling CO_2 from a lab CO_2 tank equipped with a gas regulator and a tubing for 5-10 minutes prior use. Take a pH measurement before use.

3. Pour the electrolyte in both part of the H-cell

4. Fix the lids and the battery
5. Connect the electrodes
6. Plug in the battery
7. Observe HER/CO_2R

Experiment 1. Electrolysis of Water and Bicarbonate

This experiment will make use of an H-cell, a divided electrochemical cell shaped like the letter 'H'. An H-cell uses an ion exchange membrane to enable ion transfer (i.e., ionic conductivity) between the two chambers. Either a cation exchange membrane (CEM) or an anion exchange membrane (AEM) can be used for these experiments. In the case of the AEM, the transfer of negatively charged ions (e.g., OH^-, CO_3^{2-}) from the cathodic compartment to anodic is happening. In the case of CEM, the transfer of positively charged ions (e.g., H^+) from the anodic compartment to cathodic is happening. Electrochemical processes happening on the cathode and anode in a course of water electrolysis, as well as ion transport fort AEM- and CEM-based systems are shown on the Figure S1:

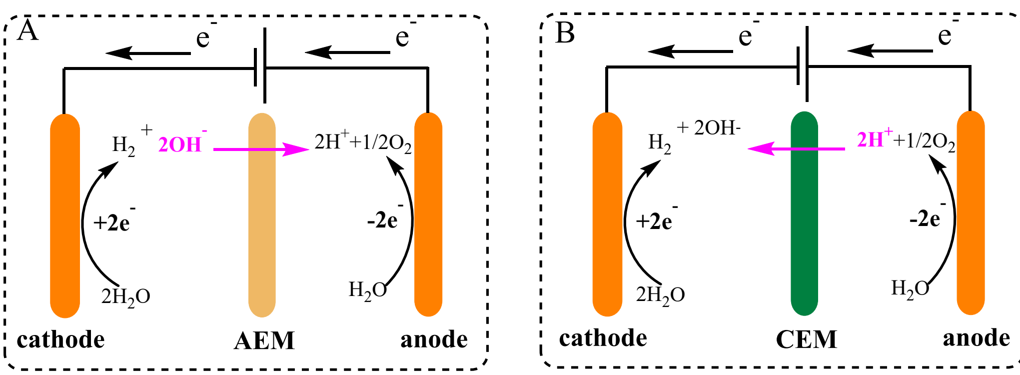


Figure S1. Schematic illustration of the electrochemical processes on the cathode and anode (hydrogen and oxygen evolution reactions, respectively) and ion transport for the electrochemical cells equipped with AEM (A) and CEM (B).

This first experiment shows the principle behind electrochemistry. In the experiment 0.5 M $KHCO_3$ solution is used as electrolyte, Cu wire is used as a cathode, Ni wire is used as an anode. 9 V battery is used as a power source. When the battery is connected, you should see bubbles at both electrodes indicating that a reaction is happening.

To begin the reaction, connect the cathode to the negative port of the battery and the anode to the positive port of the battery.

1. **Measure the amount of CO in the outcoming gas formed in a course of 10-minute electrolysis (measurements should be done every minute). Write it down. Why do you think no or very little CO is being detected? What is being produced at the cathode instead?**

2. **What do you observe at each electrode? What reactions do you hypothesize are happening? Write down the overall chemical reactions (sum of the reactions happening on the cathode and anode).**

Time [min]	[CO]*	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

*Concentration of CO is measured in ppm/umol mol^{-1} depending on the detector type.

Experiment 2. CO_2 Reduction

To oxidize or reduce a chemical species other than water, it must be present in the electrolyte. In the case of CO_2R, CO_2 is present into the electrolyte solution.

Similar to water electrolysis, either a cation exchange membrane (CEM) or an anion exchange membrane (AEM) can be used for these experiments. Electrochemical processes happening on the cathode and anode in a course of water electrolysis, as well as ion transport fort AEM- and CEM-based systems are shown on the Figure S2:

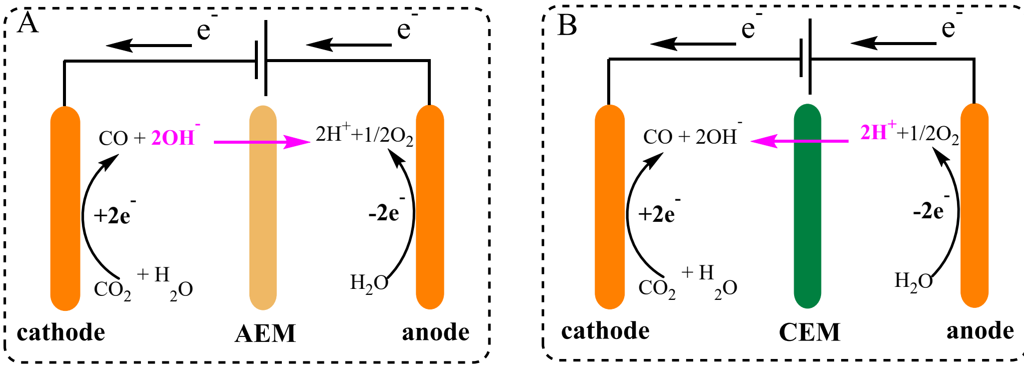
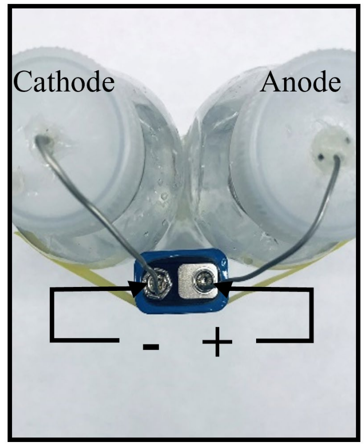


Figure S2. Schematic illustration of the electrochemical processes on the cathode and anode (CO_2 reduction and oxygen evolution reactions, respectively) and ion transport for the electrochemical cells equipped with AEM (A) and CEM (B).

In this set of experiments, CO_2-saturated 0.5 M $KHCO_3$ solution is used as an electrolyte, Cu wire is used as a cathode, Ni wire is used as an anode. 9 V batteries are used as a power source.

I.	Remove cap from cathode. Saturate electrolyte at cathode with CO_2 from a gas tank, a carbonator or a soda machine. Alternatively, exchange electrolyte for carbonated mineral water.	

II. Insert the electrodes and tighten the lids, making sure that as little CO_2 escapes as possible during the process. To begin the reaction, connect the cathode to the negative port of the battery and the anode to the positive port of the battery. Begin a timer.



III. Every minute record the concentration of CO in a table. Take a pH measurement after electrolysis to see if/how the pH has changed.

Time [min]	[CO]*	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

*Concentration of CO is measured in ppm/umol mol^{-1} depending on the detector type.

1. Using your data from this section, make a graph with the time on the

x axis, and the concentration of CO on the y axis. Be sure to include a caption. If the data is linear, fit a line to the data and put the equation in your caption (with units!). What trend(s) do you notice?

2. **What is the difference in the amount of CO detected for the electrolysis of water with and without CO_2?**

Appendix B: Surveys

B1: MLLI Survey: Pre-, Post-, and Domain-Based

MLLI Pre Test Items

When performing experiments in my chemistry laboratory course this semester, I expect…	
1	to learn chemistry that will be useful in my life.
2	to worry about finishing on time.
3	to make decisions about what data to collect.
4	to feel unsure about the purpose of the procedures.
5	to experience moments of insight.
6	to be confused about how the instruments work.
7	to learn critical thinking skills.
8	to be excited to do chemistry.
9	to be nervous about making mistakes.
10	to consider if my data makes sense.
11	to think about what the molecules are doing.
12	to feel disorganized.
13	to develop confidence in the laboratory.
14	to worry about getting good data.
15	the procedures to be simple to do.
16	to be confused about the underlying concepts.
17	to "get stuck" but keep trying.
18	to be nervous when handling chemicals.
19	to think about chemistry I already know.
20	to worry about the quality of my data.
21	to be frustrated.
22	to interpret my data beyond only doing calculations.
23	We use this statement to discard the survey of people who are not reading the questions. Please select forty percent for this question.
24	to focus on procedures, not concepts.
25	to use my observations to understand the behavior of atoms and molecules
26	to make mistakes and try again.
27	to be intrigued by the instruments.
28	to feel intimidated.
29	to be confused about what my data mean.
30	to be confident when using equipment.
31	to learn problem solving skills.

MLLI Post Test Items

When I performed experiments in my chemistry course this semester, I…	
1	learned chemistry that will be useful in my life.
2	worried about finishing on time.
3	made decisions about what data to collect.
4	felt unsure about the purpose of the procedures.
5	experienced moments of insight.
6	was confused about how the instruments work.
7	learned critical thinking skills.
8	was excited to do chemistry.
9	was nervous about making mistakes.
10	considered if my data makes sense.
11	thought about what the molecules are doing.
12	felt disorganized.
13	developed confidence in the laboratory.
14	worried about getting good data.
15	thought the procedures to be simple to do.
16	was confused about the underlying concepts.
17	"got stuck" but kept trying.
18	was nervous when handling chemicals.
19	thought about chemistry I already know.
20	worried about the quality of my data.
21	was frustrated.
22	interpreted my data beyond only doing calculations.
23	We use this statement to discard the survey of people who are not reading the questions. Please select sixty percent for this question.
24	focused on procedures, not concepts.
25	used my observations to understand the behavior of atoms and molecules
26	made mistakes and tried again.
27	was intrigued by the instruments.
28	felt intimidated.
29	was confused about what my data mean.
30	was confident when using equipment.
31	learned problem solving skills.

MLLI Item Classification

The following table lists the item classifications based on meaningful learning category (C= Cognitive; A=Affective; C/A=Cognitive/Affective) and how the item affects meaningful learning (+ = positive contribution to meaningful; - = hinders meaningful learning). These classifications are the same for both the pre and post.

When performing experiments in my chemistry laboratory course this semester, I expect…			
1	C/A	+	to learn chemistry that will be useful in my life.
2	A	-	to worry about finishing on time.
3	C	+	to make decisions about what data to collect.
4	C/A	-	to feel unsure about the purpose of the procedures.
5	C	+	to experience moments of insight.
6	C	-	to be confused about how the instruments work.
7	C	+	to learn critical thinking skills.
8	A	+	to be excited to do chemistry.
9	A	-	to be nervous about making mistakes.
10	C	+	to consider if my data makes sense.
11	C	+	to think about what the molecules are doing.
12	C/A	-	to feel disorganized.
13	A	+	to develop confidence in the laboratory.
14	C/A	-	to worry about getting good data.
15	C	-	the procedures to be simple to do.
16	C	-	to be confused about the underlying concepts.
17	C	+	to "get stuck" but keep trying.
18	A	-	to be nervous when handling chemicals.
19	C	+	to think about chemistry I already know.
20	C/A	-	to worry about the quality of my data.
21	A	-	to be frustrated.
22	C	+	to interpret my data beyond only doing calculations.
23			We use this statement to discard the survey of people who are not reading the questions. Please select forty percent for this question.
24	C	-	to focus on procedures, not concepts.
25	C	+	to use my observations to understand the behavior of atoms and molecules
26	C	+	to make mistakes and try again.
27	C/A	+	to be intrigued by the instruments.
28	A	-	to feel intimidated.
29	C	-	to be confused about what my data mean.
30	A	+	to be confident when using equipment.
31	C	+	to learn problem solving skills.

B2: EDAT prompts

Pretest: *Advertisements for an herbal product, ginseng, claim that it promotes endurance. To determine if the claim is fraudulent and prior to accepting this claim, what type of evidence would you like to see? Provide details of an investigative design.*
Posttest: *The claim has been made that women may be able to achieve significant improvements in memory by taking iron supplements. To determine if the claim is fraudulent and prior to accepting this claim, what type of evidence would you like to see? Provide details of an investigative design.*

B3: EDAT scoring rubric

EDAT Scoring Rubric (7/2010)
____ 1. Recognition that an experiment can be done to test the claim (vs. simply reading the product label).
____ 2. Identification of what variable is manipulated (independent variable is ginseng vs. something else).
____ 3. Identification of what variable is measured (dependent variable is endurance vs. something else).
____ 4. Description of how dependent variable is measured (e.g., how far subjects run will be measure of endurance).
____ 5. Realization that there is one other variable that must be held constant (vs. no mention).
____ 6. Understanding of the placebo effect (subjects do not know if they were given ginseng or a sugar pill).
____ 7. Realization that there are many variables that must be held constant (vs. only one or no mention).
____ 8. Understanding that the larger the sample size or # of subjects, the better the data.
____ 9. Understanding that the experiment needs to be repeated.
____ 10. Awareness that one can never prove a hypothesis, that one can never be 100% sure, that there might be another experiment that could be done that would disprove the hypothesis, that there are possible sources of error, that there are limits to generalizing the conclusions (credit for any of these).

Appendix C: Raw Data

C1: MLLI Raw Data

Table C1. Non-CURE MLLI results for pre- and post-course with differences and standard deviation.

Survey #	1	2	3	4	5	6	7	9	10	11	12	13	14	15	Std Dev
Pre-course	187	195	230	166	156	189	166	184	174	207	191	187	158	220	22
Post-course	202	163	211	143	149	161	132	186	197	188	182	145	164	168	24
Difference	15	-32	-19	-23	-7	-28	-34	2	23	-19	-9	-42	6	-52	22

Table C2. CURE MLLI results for pre- and post-course with differences and standard deviation.

Survey #	1	3	4	5	6	7	9	10	11	12	13	15	17	18	19	20	Std Dev
Pre-Course	233	179	245	229	177	179	262	207	211	184	184	221	170	186	130	143	36
Post-Course	215	253	240	226	224	228	258	225	219	252	208	217	193	200	212	150	26
Difference	-18	74	-5	-3	47	49	-4	18	8	68	24	-4	23	14	82	7	31

Table C3. Non-CURE pre- and post-course results of items specified by cognitive, affective, or both cognitive and affective items.

Survey #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	Std Dev	Avg
Affective pre	37	45	70	33	37	49	40	53	49	61	41	39	26	60	12	
Affective post	45	28	64	33	42	53	27	56	67	62	33	27	27	50	15	
Difference	8	-17	-6	0	5	4	-13	3	18	1	-8	-12	1	-10	10	-2
Cognitive pre	119	113	123	113	95	103	100	97	94	109	120	114	107	122	10	
Cognitive post	128	108	106	84	77	73	87	94	95	90	122	105	112	80	17	
Difference	9	-5	-17	-29	-18	-30	-13	-3	1	-19	2	-9	5	-42	15	-12
C/A pre	31	37	37	20	24	37	26	34	31	37	30	34	25	38	6	
C/a Post	29	27	41	26	30	35	18	36	35	36	27	13	25	38	8	
Difference	-2	-10	4	6	6	-2	-8	2	4	-1	-3	-21	0	0	7	-2

Table C4. CURE pre- and post-course results of items specified by cognitive, affective, or both cognitive and affective items.

Survey #	**1**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**	**15**	**17**	**18**	**19**	**20**	Std Dev	Avg
Affective pre	58	35	64	58	35	37	68	47	56	44	55	50	34	44	19	25	14	
Affective post	61	64	66	62	56	58	66	53	62	66	59	44	43	63	44	31	10	
Difference	3	29	2	4	21	21	-2	6	6	22	4	-6	9	19	25	6	11	11
Cognitive pre	134	119	142	133	122	123	146	116	116	109	107	121	107	112	96	90	15	
Cognitive post	123	139	135	124	133	132	140	135	125	138	123	136	117	102	135	89	14	
Difference	-11	20	-7	-9	11	9	-6	19	9	29	16	15	10	-10	39	-1	15	8
C/A pre	41	25	39	38	20	19	48	44	39	31	22	50	29	30	15	27	11	
C/A Post	31	50	39	40	35	38	52	37	32	48	26	37	33	35	33	30	7	
Difference	-10	25	0	2	15	19	4	-7	-7	17	4	-13	4	5	18	3	11	5

C2: EDAT Raw Data

Table C5. Non-CURE EDAT Results

Survey #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**std dev**
Pre-Survey	4	4	6	0	6	4	4	5	6	5	7	4	8	2	2
Post-Survey	6	4	5	3	5	5	5	5	5	5	4	5	5	5	1
Difference	2	0	-1	3	1	1	1	0	1	0	-3	-1	-3	3	2

Table C6. CURE EDAT Results

Survey #	**1**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**	**15**	**17**	**18**	**19**	**20**	**std dev**
Pre-Survey	4	4	5	7	6	4	4	6	6	5	5	4	6	1	0	1	2
Post-Survey	5	4	6	7	5	3	6	5	6	4	5	6	6	5	4	3	1
Difference	1	0	1	0	-1	-1	2	-1	0	-1	0	2	0	4	4	2	2