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Effectiveness of Course-Based Undergraduate Research within the General Chemistry Classroom and Their Potential Role in the Cultivation of Modern Polymaths

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Abstract Course-Based Undergraduate Research Experiences or CUREs promote student-centered learning through infusion of research principles within an undergraduate course. This is an ideal pedagogy for use in General Chemistry. CUREs provide access to research experience to a broader audience, which increases engagement and success. A CURE model was implemented in a second semester General Chemistry course at Pasadena City College, a Hispanic serving institution (HSI) community college. Student success rate in the CURE chemistry classroom increased by over 20% and students' completion rates increased over 5%. In addition, success, and completion rates of Hispanic students in the class showed no achievement gap and an over 10% higher completion rate compared to students that took the non-CURE chemistry course. CUREs also had the added benefit of providing more populous groups of undergraduates with opportunities to get a taste of real-world working scenarios that would normally be reserved for upper-level graduate students. Adopting CUREs as an integral part of an institutions' learning strategies promotes student engagement that will bridge the gaps in traditional learning, but also facilitate development of the essential soft skills required in the collaborative environment that is commonplace in working professional settings. The potential role and relationship of CUREs implementation regarding the revival and cultivation of polymathy among future students as well as its implications on the future of academic instruction based on connections made from historical and interdisciplinary observations are also explores.

Keywords Active learning, STEM equity, Course-based undergraduate research, STEAM

1. Introduction

1.1. Active Learning

The concept of active learning is based on an ancient technique that guided humanity to the current intellectual heights that are taken for granted in the modern world. The hands-on aspect of interactive learning can be traced back to our earliest ancestors, where it can be boiled down to an even simpler and innately familiar dogma known as, "monkey see, monkey do". This basic principle has served as the foundational component in the transference of information that has allowed educators to effectively teach essential skills to their students.

As the culmination of human knowledge steadily increased, so did the complexity of their ideas, quickly outpacing the technological developments that were implements of active learning, resulting in the methods of teaching gradually progressing towards more theoretical approaches. Education and literacy also became less accessible, eventually being reserved commodities prioritized for the upper echelons of society. Active learning teaching methods subsequently experienced increasing deficiencies due to the practical limitations of available technology as well as the barriers imposed by societal hierarchies.

1.2. CUREs in STEM

Fast-forward to today, active learning has earned itself many names throughout its lifetime and is currently a term that has been commandeered by the STEM fields, as their gradual embrace and implementation can be considered a relatively recent development [1]. More specifically, one current active learning manifestation, Course-based Undergraduate Research Experiences (CUREs) utilizes the infusion of research principles within undergraduate curriculum to provide early exposure to higher-level, real-world exploratory investigations [2].

Despite this association, STEM fields, particularly the sciences, were actually late to the party as the Arts and Design fields have been utilizing active learning approaches

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since antiquity [3]. Although the fields of Arts and Sciences are thought by many to be contrasting and perhaps distinctly opposite professions that require wholly different skillsets, they are in fact better categorized as two sides of the same coin. Science deals with empiricism in the same way that the arts deal with expression and emotion, as the scientific method can be applied to the approaches of both disciplines and the execution of their respective practices.

The retention of concepts learned in a classroom setting varies depending on the methodology employed. CUREs are notable examples of teaching methodologies that show promise in its effectiveness and ability to develop students' applied knowledge and stabilize their acquired knowledge [4]. Presenting a real-world problem with an unknown solution encourages students to value their accumulating referential STEM knowledge (crystallized intelligence), while also expanding their practical capabilities (fluid intelligence) by forcing them to think creatively [5]. The self-driven exploration and testing of concepts learned in class via traditional lecture settings creates a two-phase process of acquisition and application of knowledge. The application takes the form of homework review, labs, and the semester-long CUREs projects. These assignments serve as a better evaluation of the students' progress as they assess the holistic knowledge of the presented concepts and how to apply them when presented with a specific problem [6]. The course labs serve as incremental chapter-based concepts that feed into the success of the final project, as the CUREs projects required the cumulative understanding of multiple concepts learned throughout the course. On their own, and without reinforcement through the labs, the concepts learned are treated as standalone topics whose importance only exists until the next exam and are often quickly forgotten.

The inclusion of CUREs projects not only enhances learning retention and critical thinking skills, but also develops the soft skills needed to work in real-world collaborative environments [7]. Soft skills like communication, coordination, delegation, understanding of group dynamics, socializing, etc. are just as important, if not more important, than the learned concepts acquired through traditional schooling environments. The CUREs projects provide opportunities to learn from a series of shared beneficial traumas that help to create memorable bonds between peers, form different connective pathways to the learned concepts, as well as being catalysts for overall personal growth [8]. These learned concepts have the added benefit of having more triggers and devices associated with their recall due to the variety of experiences that have taken place throughout the course of the project [9]. The real value of CUREs projects is their novelty and ability to provide opportunities for a significant number of undergraduate students that simulate group learning scenarios and largely self-driven exploratory experiences that are commonplace in the professional working STEM community. CUREs projects are also able to provide these undergraduates with campus commodities such as mentorships with faculty members and in some cases, access to the campus facilities, giving the undergraduates a competitive edge in hands-on experience [10].

1.3. Similarities Between the Arts and STEM Pedagogies

Trade schools, particularly those with a focus on art and design, have utilized hands-on active learning approaches for many centuries before STEM caught on to its advantages [11]. While it may be tempting to attribute the early implementation of active learning methods to the nature of creative subject matters, which do require a greater emphasis on the skillful manipulations of learning materials, art and design theories are also taught as a sizable portion of the curriculums. The hands-on active learning components serve to reinforce those theories in the form of muscle memory and analytical observation skills that can offer a valuable dimension of fundamental literacy for STEM majors.

Scientists are often incorrectly viewed as the antithesis of a skilled craftsperson, when the opposite is true, and that the lab work of a scientist is analogous to the artwork of an artist. Just like an artist has their studio and various mediums by which they create their art, a scientist has their lab and various instruments by which they perform their experiments. The works of artists and scientists both require careful and meticulous planning prior to attempting the completion of their artworks and/or experiments using the skills they have honed as part of their vocational training. Artists and designers solve the problems presented by their clients by using healthy amounts of curiosity, observations, research, and hypotheses formulations, which are then turned into experimentations that are observed further before arriving at a final iteration of their proposal that adequately satisfies their client's criteria. Striking similarities can be identified between the design and scientific methods as scientists and artists follow the same protocols when designing and performing their experiments [12].

1.4. STEAM Pedagogies & Interdisciplinary Collaboration

The stagnant academic environments of STEM can be made reactive and fertile with the addition of the Arts as a catalyst to jump start the creative abrasion needed to make new connections and form different perspectives that bridge the gaps between seemingly unrelated concepts of various disciplines, thereby promoting the cultivation of intellectual diversity among the populace of traditional STEM disciplines. This type of creative abrasion between Arts and Science has seen many uncredited successes throughout history and can be identified in the omnipresent innovations that are routinely unacknowledged despite their importance in modern civilization. The additive RBG color model that illuminates all electronic screens uses the combination of red, blue, and green pixels to produce the full spectrum of colors in a way that is nearly identical to how artists used dots in Pointillism techniques to create their artworks. Nobel Laureate Alexis Carrel used his expertise in lacemaking to develop the stitching techniques used in medical surgeries.

Samuel Morse (telegraph) and Robert Fulton (steamship) were both distinguished American artists before they invented their respective magnum opi/opuses [13].

The subtle differences of each practice hidden within their similarities can serve as a gateway for the investigation and discovery of valuable interdisciplinary insights regarding successful and efficient teaching methods. One famous example of this amalgamation is the short-lived German Bauhaus School and their approach to design, which hoped to unite the seemingly polar principles of mass production with artistic individualism as well as striving to consolidate aesthetics and everyday functionality [14]. Essentially, the Bauhaus elevated the mass production of artisanally designed functional goods to newfound levels of appreciation equivalent to the non-functioning fine art typically found in galleries, resulting in a hybrid of both extremes of the design spectrum, thereby establishing modern industrial design as the prevalent field it is today. The driving idea of the Bauhaus was the pursuit of unifying all forms of art into a singular and ideal "'total' work of art".

Currently, the benefits of STEAM-based pedagogies have been recognized and adopted by top design schools like the Rhode Island School of Design (RISD) and Art Center College of Design (ACCD) [15]. RISD added its support for STEAM with the company of the U.S. Department of Education and the National Science Foundation [16]. ACCD, curriculums are modeled directly after the Bauhaus, offer STEAM-focused workshops as part of their ACX programs as well as fully accredited Bachelor of Science and Master of Science certifications in various disciplines of Industrial Design [17]. On even higher organizational levels, the STARTS (Science+Technology+Arts) initiative funded by the European Commission was created to promote the interdisciplinary collaboration of different backgrounds necessary to contribute meaningful insights and perspectives that led to innovative ideas [18]. These programs piggyback off the emerging learning revolution known as "the maker movement", which harnesses the innate creative impulses of an individual and use hands-on problem-solving skills as a method of teaching traditionally rigid subjects. The recent explosion of this movement was brought about by developing technologies becoming more readily accessible, which only serves to accelerate the movement further [19].

The key takeaway from these academic integrations is that analogous similarities can be found across seemingly unrelated disciplines, whose differences may end up being the missing piece of the puzzle for the advancement of another discipline [20]. This is the exact situation that the STEM and the Arts fields find themselves in today. Educational institutions are beginning to make reluctant progress towards that direction but are still largely uninformed to the answer potentially sitting in plain view. STEM fields, especially the sciences would greatly benefit if they were to be taught and treated like the trade school pedagogies of Art and Design fields as they have been tried and tested, reliably producing skilled artists, designers, and tradespeople for generations.

1.5. Constructivism and Piaget

These ideas echo the sentiments first proposed by the Constructivist theory in education, which also borrows from the theory of cognitive development created by Swiss developmental psychologist, Jean Piaget [21]. Constructivism recognizes that the student's own unique experiences prior to beginning any academic instruction, serve as the foundation for their overall ability to understand and acquire knowledge [22]. Constructivism gets its name from the idea that students are constructing knowledge out of their own experiences, which suggests that every individual student has a unique method of learning that works best for them, thereby implying that broad spectrum pedagogy solutions may not be as beneficial as once thought for a large portion of these differently minded students shaped by their pre-academic experiences [23]. Many of the tenets of Constructivism fall neatly in line with the goals of widespread CUREs implementation, as problem-based and inquiry-based learning methods are considered signature Constructivist pedagogies.

1.6. Cultivating Polymathy and Creativity: The Role of the CURE Project

The combination of active learning, CUREs, STEAM and other interdisciplinary practices, Constructivist theories of education, and Piaget's theories on developmental psychology, all converge at a single nexus that is polymathy. Judging by what CUREs are able to achieve, polymathy is the next logical step in the academic development process.

The term polymath refers to a person with an extensive wealth of knowledge that spans multiple disciplines from which they can draw upon to solve complex problems. Polymaths are the result of the successful integration of the expert-level depths of knowledge typically found in specialists and the superficial breadth of knowledge in a variety of interests typically found in generalists. Both elements each have their respective advantages as well as their complementary tradeoffs. Specialists have the advantage of deep and sophisticated understandings within their field of expertise at the cost of being more narrowly restricted by the intensity of their focus. Conversely, generalists have the advantage of a comprehensive diversity of knowledge at the cost of being limited to shallow understandings in their fields of interest [24]. Many individuals often come to possess aspects indicative of both specialist and generalist tendencies and despite having the prerequisite components of polymathy, most are unsuccessful at becoming polymaths because they lacked the opportunity to develop the necessary thinking skills that would allow them to make abstract connections between their realms of knowledge and integrate them properly.

Throughout history, polymaths have been held in reverence for being ahead of their time and pushing the boundaries of human knowledge with their significant contributions in their fields of study [25]. These Renaissance men and women include the company of Archimedes, Leonardo DaVinci, Marie Curie, and even Prince. These scholars could be considered polymaths who have successfully integrated specialist and generalist tendencies relative to their awareness of the world. With the rapid development, accumulation, and modernization of global knowledge, a new "intellectual climate" to which polymaths of all kinds have access to a wealth of knowledge. The resulting "passive polymaths" possess diluted essences of the classic polymath, which frequently experience further dilutions in polymathic capabilities due to the general societal support of specialist mindsets and the overall societal abandonment of generalist integrations in education and career opportunities. The increasing dilution of quality regarding the regular reproduction of polymaths has led some esteemed modern-day scholars to refer to them as an endangered "intellectual species" who are worthy of our dedicated conservation efforts [26].

Practicing polymathic thinking requires the ability to combine different networks of information in novel and unconventional ways, forming the basis of an inherently interdisciplinary mindset. This process is made possible by what is commonly referred to as creativity, which is a hotly debated topic with regards to its role and importance in scientific and creative fields and whether it is exclusive to one another. Recent scientific literature argues that the creative process is universal and is not exclusive to any discipline. Even though the creative end product is different, whether it is an abstract painting, mathematical model, scientific experiment, or Shakespearean sonnet, both STEM and Arts disciplines utilize the creative process and use the same intuitive thinking tools that lead to the generation of creative ideas [27]. Nobel Laureates were observed to have significantly higher averages of the number of avocational activities compared to other organizations of esteemed scientists, indicating a strong correlation between arts and crafts and success in the sciences, and vice versa [28]. The patterns observed in the Nobel Laureate data suggests that polymathy can be considered a strong indicator of the degree of success in an individual's career [29].

Everyone has the potential for varying degrees of polymathy and creative accomplishment can be nurtured given the proper environment, even if the individual is not a polymath. Barring any variables that are unique to the individual's personality, the three general requirements were identified for developing creativity, which are intelligence, motivation to be creative, and an environment that is supportive of creative expression [30]. The CURE-based classroom is ideal for creative expression through research and therefore will promote an environment where students are encouraged to reach a level of polymathic mastery in their chosen field.

The advantage of polymathic pedagogies allows prospective STEM/STEAM students that are still relatively early in the academic careers to develop their polymathic abilities by using CUREs and CUREs-like implementations. Conveniently, CUREs projects manage to satisfy most, if not all, of the basic requirements needed to promote the polymathic augmentation and reconstruction of traditional pedagogies. CUREs indiscriminately provide the ideal environment for creative achievement and democratize opportunities for STEM/STEAM majors, effectively leveling out the external factors responsible for restrictions in polymathic growth, resulting in the widespread "activation" of traditionally overlooked student potential. The open-endedness of the project prompts is designed to encourage and reward the traditionally underrated ways of divergent thinking, which breathes new life into the sterile learning environments of broad-spectrum STEM pedagogies. The skills and perspectives shared among students through the course of CUREs promotes the development of the tools and strategies needed for innovative thinking and effective collaborative efforts, as well as enabling students to unlock and understand their own learning preferences through instances of creative abrasion [31]. Working with the various unique learning preferences and experiences of a more diverse group of students, can help to fortify the viability of the "passive" and "classic" polymaths produced by academic institutions, resulting in potentially greater accumulations of innovative individuals that retain higher concentrations of polymathic qualities more akin to that of the "classic polymaths" of the Renaissance.

The educational path taken by the quintessential "Renaissance Man" has since been abandoned by the modern education systems, as they tend to favor the mass production of graduates who have fulfilled the requirements of their vocational training that promotes the compartmentalization of acquired knowledge and prepares them for their reserved role in a specialist-favored society. This creates a major obstacle for the conservation efforts towards polymaths as they require more holistic approaches to education if they are to thrive and recover from being an endangered species [32]. Incidences of polymathy, or even creativity, should not be treated as coincidental and esoteric phenomena, but rather the ideal end goal of higher education, as CUREs makes it possible to cultivate both and make them more commonplace within academia. If educators are made aware and cognizant of the requirements that foster creativity, polymathy, and the subsequent innovations, then the implementation of CUREs and CUREs-like components in modern pedagogies may very well be the first step in achieving such surpluses of creative human capital [33].

2. Materials and Methods

2.1. Participants

CURE and non-CURE class data was collected at Pasadena City College for second semester General Chemistry over a period of four years encompassing the 2015 Fall semester through 2019 Winter semester. The non-CURE classes consisted of providing students with a lab manual with worksheets to fill out at the conclusion of experiments on kinetics using the clock reaction, equilibrium based on La Chatelier's Principle, thermodynamics using borax, two electrochemistry experiments and one experiment on poten-tiometric titrations that included a written report. Students were not given prior notice at the time of their registration that CURE-based pedagogy would be used. Classes were not advertised as such and maintained their anonymity until the first day of class where students were informed in person through syllabi that outlined the active learning method of delivery and intent of the class. The statistical data supporting active learning was presented and general rules and guidelines that were unique to the active learning class was explained. Students were not provided with information that made them aware that other sections of the same class teaching pedagogy.

2.2. Project Parameters & Student Deliverables

The concept of heavy metal remediation is not uncommon in today's industrial landscape. Students were initially introduced to the case of Hinkley, California and hexavalent chromium contaminating the groundwater. The Pacific Gas and Electric Company (PG&E) had dumped approximately 370 million gallons of chromium-tainted wastewater into ponds that resulted in the spreading of hexavalent chromium into the local fresh water supply [34]. Hexavalent chromium, or chromium(VI) is a cheap and effective anti-rust compound used by PG&E to keep their natural gas pipelines in their compressor stations clean and rust free as natural gas needs to be constantly pressurized to facilitate liquid transportation of the resource. Chromium(VI) compounds are known to be highly carcinogenic, which manifested as a higher concentration of people in the area developing some form of cancer. At the time, chromium(VI) ingestion was not considered to be a cause of cancer. PG&E had been continuing this practice from 1952 through 1966.

This case was brought to attention by a legal clerk, Erin Brockovich, who successfully sued PG&E for their involvement in the contamination resulting in a $333 million dollar settlement. After the lawsuit, the remediation process taken on by PG&E was largely inefficient and unsuccessful, as Hinkley essentially became a ghost town primarily due to the inconclusive nature of the surrounding area's carcinogen concentrations. By 2013, PG&E's remediation strategy incurred a $750 million dollar investment that included the construction of a half-mile long concrete barrier to contain the expanding plume of contaminated water, the pumping of ethanol into the ground to convert highly toxic chromium(VI) to the significantly less toxic chromium(III), and the planting of acres of alfalfa with the hope that the alfalfa would absorb and store the chromium (VI) within its plant tissues. By their own estimates, it would take another 40 years to complete the remediation process [35].

This scenario was introduced, and a research-based project was designed to simulate the hexavalent chromium remediation based on concepts learned in second semester general chemistry. Due to its toxicity, hexavalent chromium was omitted and replaced with substitute metal contaminants in the form of copper and iron chlorides to provide a safer and more accessible alternative in a community college laboratory setting. Similar to how the chemists at PG&E would have had to solve the problem at hand, students would be given a sort of trial run at resolving the contamination issue. The exploration of other possible procedures allows for the contextualization of otherwise difficult-to-grasp material learned in class.

Students in the chemistry course were encouraged, but not required, to work in groups of three or four and collaboratively work towards designing and proposing an experiment that could potentially solve the real-world contamination problem posed by the project. The project was performed over a sixteen-week semester. A total of eight five-hour class periods were made available for students to work on the project in lab. The other eight weeks students worked on experiments in kinetics, thermodynamics, electrochemistry, equilibrium, and coordination compounds. During the week's students did not work on the CURE-based project they were encouraged to meet with their groups and work on literature reviews, formulate experimental design and perform data analysis. Student groups were expected to deliver an experiment design, data analysis and conclusion in the form of a poster presentation that included an outline of their procedures and photographic documentation of observations, as well as a section of self-reflection regarding the nature of their procedures' failures and what could have been done more effectively. These projects were submitted digitally via email to the professor who would then assess the accuracy and precision of their conceptual interpretation as well as the effective application of learned concepts and laboratory techniques. The goal would have been to completely separate and isolate the constituent components from the starting heterogeneous mixture thereby resulting in theoretically clean and drinkable water. The professor took the position of being unaware of any single "correct" procedure that could adequately separate and remediate the tainted water. The ambiguity of the potentially unknown solution to the project added to the exploratory and self-discovering nature of the students' experiments. Students were not graded on the success of their proposals, as they were not expected to succeed in separating the mixture, but rather on the depth and thoroughness of their investigation.

2.3. Example Project

Toxic heavy metals in water cause damage to fresh water sources nearby. This ends up being the cause of many health problems for humans. A solution to this problem is to find a way to separate the unhealthy impurities from the tainted water, resulting in a more potable, or drinkable water.

A heterogeneous mixture of copper(II) chloride, iron(III) chloride, sodium chloride, and sand was prepared to act as contaminants meant to simulate dirty water (**Figure 1**). Students were shown each solution before mixing to demonstrate physical properties. The blue copper (II) and yellow iron(III) solutions when mixed with solid sodium chloride and sand will form an aqueous green mixture whereas all ions are soluble in water with sand remaining a brown solid. Chromium(VI) was used in the first iterations of this project. However, due to its increased safety and health risk the project evolved to simulate contaminated water using copper(II) and iron(III) ions, which are less toxic and safer for a community college lab environment. Possible separation techniques are similar in either the heterogeneous mixture being chromium(VI), or the copper(II) and iron(III) ions. By applying concepts and techniques learned in both General Chemistry I and II, students were instructed to design an experiment to separate out the copper(II) and iron(III) ions, salt, and sand from the heterogeneous mixture as a potential method to remediate previously unsafe drinking water.

Student groups designed disparate experiments (**Figure 2**). The common first step was to physically separate the sand from the solution using filtration. Once only the metal ions and salt were left, electrochemical principles via voltaic or electrolytic cells were often used to separate the copper and iron metal ions from each other. In one instance, the electrolytic cell utilized a copper cathode accumulating copper solids, in conjunction with a carbon anode in which chlorine gas was emitted from the reaction. The electrolytic cell was placed in a hood for safety purposes. Once the metal solids were removed, the remaining solution had its pH determined to ascertain if within the range of drinkable water. After confirming, the remaining solution was boiled to evaporate the water and reveal the remaining salt. This is one example among many student groups have designed. Several student groups also used magnets placed in the solution, left over a week to observe what happened.

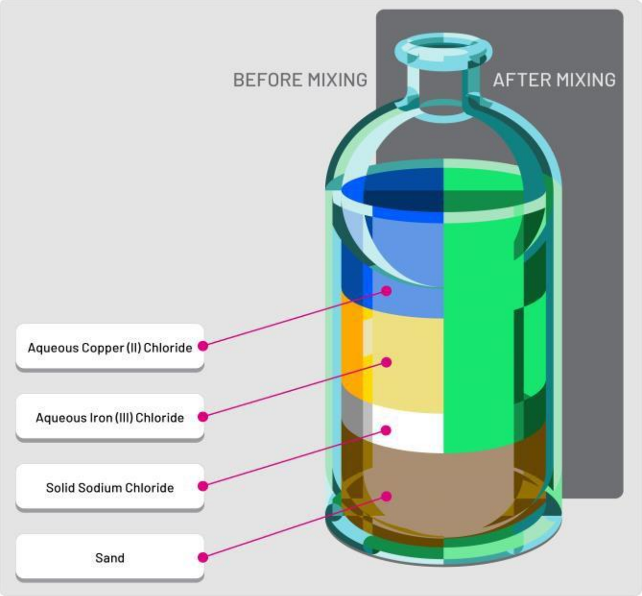
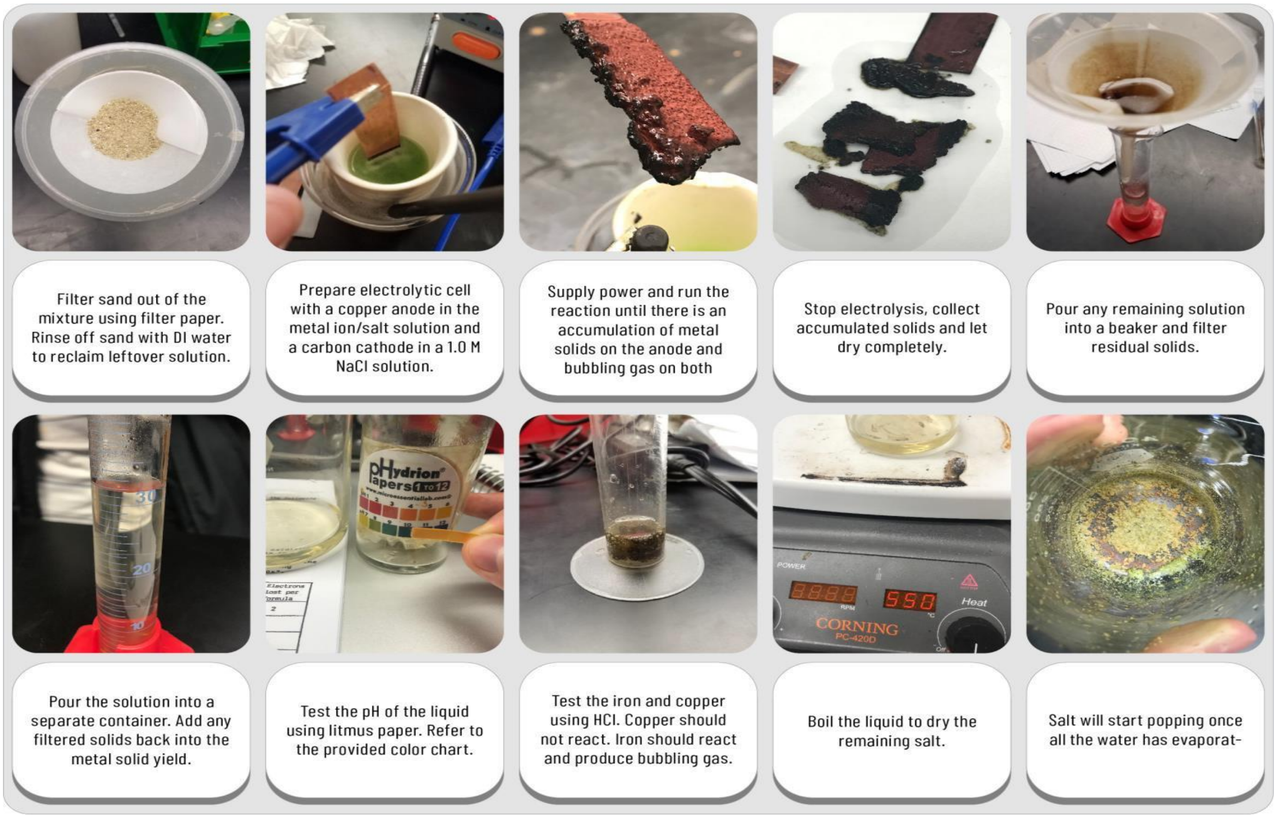


Figure 1. All students began with a heterogeneous mixture that contained the following substances: copper (II) chloride, iron (III) chloride, sodium chloride, and sand. Before mixing shows colors and states of components turning to a green aqueous solution with sand after mixing



Filter sand out of the mixture using filter paper. Rinse off sand with DI water to reclaim leftover solution.

Prepare electrolytic cell with a copper anode in the metal ion/salt solution and a carbon cathode in a 1.0 M NaCl solution.

Supply power and run the reaction until there is an accumulation of metal solids on the anode and bubbling gas on both

Stop electrolysis, collect accumulated solids and let dry completely.

Pour any remaining solution into a beaker and filter residual solids.

Pour the solution into a separate container. Add any filtered solids back into the metal solid yield.

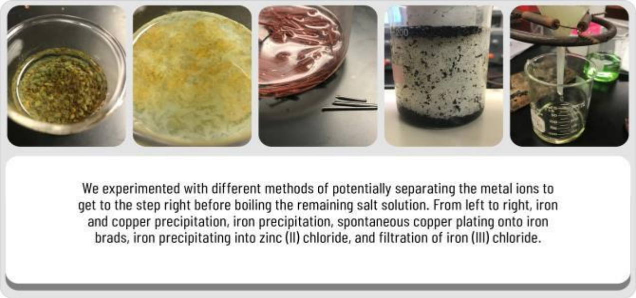
Test the pH of the liquid using litmus paper. Refer to the provided color chart.

Test the iron and copper using HCl. Copper should not react. Iron should react and produce bubbling gas.

Boil the liquid to dry the remaining salt.

Salt will start popping once all the water has evaporat-

Figure 2. Example of an experimental procedure designed by Chemistry 1B students for the CUREs project. Various chemistry concepts were applied in order to separate the initial components. Experiments demonstrated variety in both their methods and degree of success among students



We experimented with different methods of potentially separating the metal ions to get to the step right before boiling the remaining salt solution. From left to right, iron and copper precipitation, iron precipitation, spontaneous copper plating onto iron brads, iron precipitating into zinc (II) chloride, and filtration of iron (III) chloride.

Figure 3. Example pf the trial-and-error methodology experienced by students during the course of the CUREs project

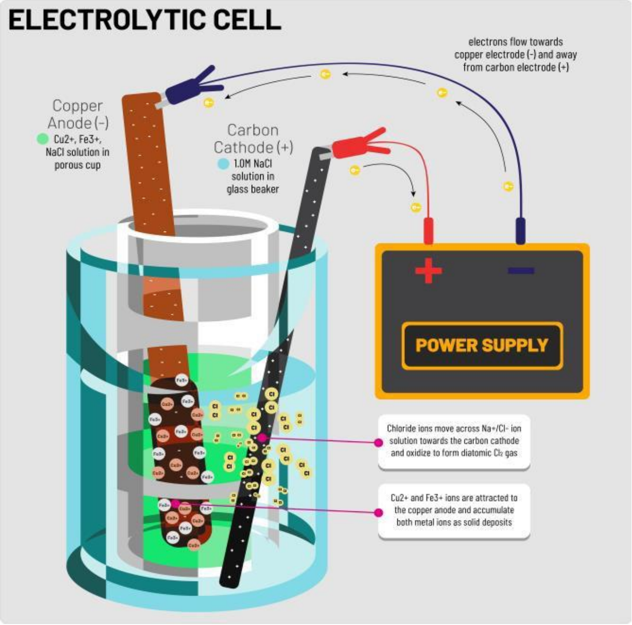


Figure 4. Example of a student's electrochemical diagram in their procedure included in the group's final presentation poster, which is the basis of grading for the CUREs project. Students were not required to be 100% correct in their understandings and assumptions as long as they demonstrated an informed vision towards their goal. Conceptual mistakes could be overlooked in the final grading provided that the results were still mostly in line with what was taught during class lectures

Different groups had varying degrees of success in the separation and utilized a wide range of concepts learned throughout the course of the semester. Other methods were tested through a series of trial and error, which only served to reinforce the applications and limitations of certain chemical properties and techniques. These concepts and methods included but were not limited to precipitation, magnetism, solubility, reactivity and spontaneous plating, evaporation/distillation, utilizing unique chemical properties, heating, pH manipulation, etc (**Figure 3**).

The project coincided with chapters on electrochemistry, equilibrium, thermodynamics, and kinetics. The electrochemistry chapter was especially useful to students as this technique proved to be the most reliable way for students to separate the metal ions (**Figure 4**), which was where most of the difficulty occurred. The timing of the course instruction and subject material synergistically enhanced the learning experience because the students reached an Impasse when only relying of the concepts prior to electrochemistry. Students were being fed information early in the project that would eventually inform their decisions during their dedicated lab hours.

3. Results

3.1. Student Success Data

The success of the course-based undergraduate research experience course was measured in three ways. One, comparison of completion (either transfer or degree) for students in the General Chemistry II CURE verse non-CURE course (**Table 1**). Two, measuring success rate compared to non-CURE courses (**Table 2**) and three, using the American Chemical Society Second Semester General Chemistry Exam. To better elucidate if the utilization of CUREs is effective in closing the achievement gap, Hispanic student success and completion were compared with Asian/White student success and completion rates.

Table 1. Completion percentages in CURE-based and non-CURE-based Chemistry 1B (number of students)

	CURE Class	Non-CURE Class
All Students	59.6% (178)	54.9% (1123)
Hispanic Students	51.7% (58)	40.6% (313)

Overall success rates were 89.2% for the CURE-based General Chemistry II, with no observable achievement gap between Asian/White students and His panic students. This is compared to an achievement gap of 22.4% when comparing the non-CURE General Chemistry II class, in which Asian/White students succeeded at a rate of 72.9% compared with a 50.5% success rate for Hispanic students. There was a 38.7% difference in success rates when comparing Hispanic students in the CURE-based class to non-CURE course. The only difference between the two courses was the CURE-based lab component. Lectures were identical, though electrochemistry was covered earlier for the CURE class to better prepare the students. Exam questions were obtained from a Canvas database of shared questions for the course. The second semester General Chemistry ACS exam scores were given at the conclusion of the course as a final and scores compared with ACS national norms. After using a two-tailed t-test it was concluded with 95% confidence that students from CURE-based learning course achieved equivalent scores to national norms (**Table 3**).

Table 2. Success rates for Chemistry 1B CURE and traditional labs

Chem 1B	Number of Students		Success
CURE Lab	223	Asian/White	89.2%
	112	Hispanic	89.3%
Traditional Lab	617	Asian/White	72.9%
	293	Hispanic	50.5%

Table 3. Chemistry 1B ACS Exam scores and norms

	Number of Students	**Mean**	**Standard Deviation**
CURE-Class	211	38.3	11.4
ACS Norms	>1000	37.9	10.9

4. Conclusions

Polymathy is an already widespread phenomenon that has been kept under the radar because of the many names it takes on. Hybridized areas of study have seen a steady increase in creation and innovation. These instances of successful and profitable deviations from the established knowledge pool have been incorrectly treated as fairly rare and isolated occurrences, often attributing their achievements to the rare and talented individuals that led their endeavors. While it is true that rare and talented individuals spearheaded their visibility to the world, these individuals that excel in thinking outside of the proverbial box are actually much more common than we realize. The problem is that current pedagogies are antiquated in the sense that they are typically ill equipped to foster these unique and gifted mindsets, as the established criteria for identifying these traits are harshly selective and dichotomous by design. What this system fails to account for are the individuals that fall in between the criteria, who exhibit signs of milder levels of gifted potential that are often overlooked and ignored but can nonetheless be cultivated to great success provided that their instructors are cognizant of their learning needs and preferences. Unfortunately, these students of medi-um-level giftedness become victims of the system's criteria that decide the required threshold for giftedness consideration. In the eyes of the systems in place, these students have just enough giftedness to shift into either the top or bottom of the academic success spectrum with no accommodations for those in between, resulting in an ultimatum of academic success via forced conformity.

Instead of a rigid system of teaching that forces conformity and snuffs out potential talent and giftedness in its students, a more flexible and open-ended methodology would likely be more nurturing of this untapped source of human capital. For too long, there has been too much of an emphasis on the extremes of the classroom, where the students in the high and low ends receive the most attention, while the students in the middle receive the least attention. Modern schooling has become a numbers game in which school districts and institutions compete for funding based on the reported median success rates of their students. This is where CUREs hold a major advantage, in that the open-ended nature of the projects allows for students from all areas of the academic spectrum success, as well as other social/economic/cultural demographics, to contribute their unique perspectives and experiences in a collaborative environment that is supportive of their self-driven and exploratory investigations of their interests.

The body of literature supporting CUREs implementation is constantly growing, as institutions across the nation and the world have seen consistent benefits in the use of active learning principles and procedures. Of course, more studies and experiments would have to be conducted over longer periods of time with significantly larger sample sizes to obtain more conclusive data and results, but the data obtained from our study indicates that the support for CUREs is not unfounded.

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