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Technology-based Culturally Relevant Chemistry Education (CRCE)

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TECHNOLOGY-BASED CULTURALLY RELEVANT CHEMISTRY EDUCATION (CRCE)

BY

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DISSERTATION ACCEPTANCE PAGE

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This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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This dissertation is dedicated to my husband, and my children I had while doing this degree. I could not have gone through this journey without your support. We did it!

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CRCE…………………………… Culturally Relevant Chemistry Education

CRE……………………………....Culturally Relevant Education

STEM……………........................Science, Technology, Engineering, and mathematics

LGO…………………….………..Learning Goal Orientation

TV……………………..……….Task Value

SE……………………..………..Self- Efficacy

SR……………………..…..…… Self- Regulation

CAST……………........................California Standard Tests

ACS Exam……………................American Chemical Society's General Chemistry Test

CU……………...........................Conceptual understanding

CM-G…………….......................Conceptual mismatch or gap

I-CU………………………...........Incorrect understanding/poor conceptual knowledge

R-PER…………………….......... Personal application

R-PRO………......................…. Professional application

I-OL…………………………........ Impact on life

D2L………………………….......... Desire 2 Learn

LMS………………………......…. Learning System management

CITI program……........................Collaborative Institutional Training Initiative program

IRB………….........................… Institutional review board

CLASS……..........................Chem- Colorado Learning Attitudes about science survey

ASCI……..........................…Attitude toward the Subject of Chemistry Inventory (ASCI)

MOSART……Misconceptions-oriented Standards-based Assessment Resources for Teachers test.

SALES……….Students' Adaptive Learning Engagement in Science questionnaire

ABSTRACT

TECHNOLOGY-BASED CULTURALLY RELEVANT CHEMISTRY EDUCATION (CRCE)

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The relevance of chemistry concepts and principles remains a challenge for most students enrolled in college chemistry courses. Part of this problem is the disconnect with what students experience in their every-day lives, and how the material, specifically chemistry content is presented via textbooks, lectures, and laboratory teaching. Moreover, the teaching of general chemistry has traditionally focused on traditional, instructor-centric expository delivery of course materials, that treats students as empty vessels devoid of prior knowledge.

Students prior knowledge and experiences are crucial in shaping their understanding of scientific concepts and principles. Even students with relatively low expectations for success in science display more interest and better performance when provided opportunities to connect the relevance of science to their lives[1, 2]. Despite changes in the teaching and learning of chemistry as called for by the chemical education experts and researchers, Culturally Relevant Chemistry Education (CRCE) has remained a distant goal. This can be attributed to the lack of curricular materials to teach chemistry in a meaningful way. This study addressed this gap through the development of modules that

emphasize the relevance of scientific (chemistry-based) practices from a cultural and traditional standpoint.

The study presents details of a) rationale for, and the development of CRCE modules channeled as texts and videos b) piloting and revision of CRCE modules and c) implementation of CRCE modules in a general chemistry course and d) complete integration of modules in a large enrollment general chemistry survey course section. The study is informed by three theoretical frameworks namely Culturally Relevant Education (CRE) framework, Mayer's cognitive theory of multimedia learning, and constructivism and social constructivism.

Three research questions that focused on student academic performance, conceptual understanding, student attitudes towards the subject of chemistry, and motivation and self-regulation in science were answered for each stage to draw conclusions on the impact and effectiveness of modules. The study involved a sequential exploratory research design with emphasis on both qualitative and quantitative data collection and analysis to answer the research questions.

At the beginning of study, a pilot study that tested the feasibility of newly designed modules integrating the cultural practices in the chemistry content was investigated. Piloting of CRCE modules focused on impacting student's academic performance, conceptual understanding, attitudes in chemistry as well as motivation and self-regulation. Key findings from the piloting of the developed modules are presented. These findings indicate (a) CRCE modules that merge students own experience with the cultural practices of a place leading to meaningful learning, (b) students likely to improve in their academic performance and (c) student attitudes and motivation with science experiences a positive shift during the CRCE modules pilot efforts.

Since general chemistry is a required course for programs in health sciences, agricultural sciences, and science related careers, the impact of implementing and integrating CRCE modules in lecture section of a general chemistry course on students' academic performance, conceptual understanding, attitudes, and motivation and self-regulation was investigated. Results from implementation stage of CRCE study showed a significant impact of the implementation of CRCE on students' academic performance, conceptual understanding, attitude, and motivation and self-regulation. Also, analysis from integration stage of CRCE modules indicated an improvement on academic performance, conceptual understanding, and motivation and self-regulation but there was some inconsistency in the impact of integrated CRCE modules on students' attitudes. The inconsistency was rather related to the shift of teaching to online mode during the COVID pandemic and that the modules had maintained a positive impact on student attitudes.

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Keywords: Culturally Relevant Chemistry Education, curriculum development, academic performance, conceptual understanding, student motivation and self-regulation, attitudes, cultural practices, Native Americans.

CHAPTER ONE

INTRODUCTION

1.1. Introduction to Culturally Relevant Chemistry Education (CRCE)

Reviews on current science education research highlight the crisis of disappointingly poor academic performance and low student retention with higher DFW (grades of D, F and Withdrawal)[1-3]. According to these reviews, the failure of institutions is mainly attributed to the inability of the curriculum and classroom practices to ignite student interest and foster student engagement in chemistry[1, 3]. Despite curricular reforms and call for changes in undergraduate chemistry instruction to make it student-centered, several deficiencies remain in both the curricular and the teaching practices that supplement these curricular resources. And the question is: (1) Why is there a problem with student performance and engagement that reflects in student motivation and self-regulation of learning? (b) Why is student conceptual understanding still an issue despite efforts from several researchers, academics, and funding agencies to overhaul the undergraduate chemistry education, specifically for first year chemistry courses that serve as filters or pipeline for STEM majors and careers?

A student-centered practice keeps students at the front-and-center with the overarching goal of benefitting learners by providing them curricular resources, classroom experiences, and using the teaching approaches that are effective in advancing student knowledge and peak student interest in the discipline. In a discipline like chemistry which is abstract and requires the integration of macroscopic, symbolic and particle level models (representations) to coherently understand the fundamental ideas and concepts, it is important that the instructors pay attention to several aspects that impact students growth and understanding of the chemistry. The problem is that often novice instructors (or traditional teachers) remain oblivious of the impact of their teaching related decisions, “think like a chemist” views on the nature and practice of chemistry in our students[4]. The decision making, involved in teaching also includes choice of curricular resources and how these resources such as textbooks and technologies are used or integrated in the teaching and learning. The signals sent out by instructors are not generated in isolation - these signals also reflect and convey the deficiencies that are inherent in the curricular resources that are used for teaching.

Considerable efforts focused on development and integration of a technology-based Culturally Relevant Chemistry Education (CRCE) for the general chemistry course was investigated. The impact of these CRCE modules on the contextual understanding, academic performance, motivation and self-regulation, and attitudes among diverse undergraduate students in a Midwestern University within United States were studied in-depth. Five (5) modules that translate traditional indigenous Native American practices with their associated chemistry explanations were developed. Each module addresses specific topics such as matter and measurements, chemical bondings, chemical reactions, solutions, and acids and bases.

More broadly, these modules demonstrate the fundamental chemistry principles and practices in our physical environment and provide a strong practical component to students to fully engage with the subject material. It was anticipated that introducing the

CRCE modules to large classroom will help to overcome the discontinuity between indigenous and western scientific epistemology contexts[5].

This thesis presents an overview of the development of the CRCE modules, and the impact of these CRCE modules on a) student academic performance and conceptual understanding (cognitive aspects); student attitudes towards the subject of chemistry, learning of science , student motivation and self-regulation (affective aspects). The effectiveness of CRCE modules and their cognitive and affective aspects among students were studied using an exploratory sequential research design. [6] In order to address that the study was thoroughly conducted, a pilot study was conducted before introducing modules into a large enrollment classroom.

1.2. Diversity in chemistry teaching: Current curriculum and persistent gaps

Globally, every country is involved in developing scientific literacy to help foster the skills, knowledge and abilities needed to adapt to life in a scientific world. More emphasis has been laid that scientific literacy should cover a broad spectrum of science competencies which reflect the national curriculum[7, 8]. For students to be scientifically literate, students should:

- Understand characteristic’s components of science as a form of human knowledge and specifically develop an understanding of the process of scientific inquiry.
- Be aware of how science and technology shape our material, intellectual, and cultural environments.
- Be able to ask questions pertaining to the discipline and engage in the process of making sense of the scientific phenomenon to draw evidence-based conclusions.

- Be willing to engage in science-related issues and with the ideas of science, as a reflective citizen.

But to foster scientific literacy among college students, a diverse group of students are required to enroll in science, technology, engineering, and mathematics (STEM) courses such as general chemistry. Chemistry courses are prerequisites for STEM majors. Due to the complexity of ideas presented in chemistry topics and its abstract nature, students often struggle to make sense of chemistry and connect it to the real-world experiences. Students who are not proficient in thinking in abstract terms find it difficult to connect their understanding of large scale (macroscopic) representations with symbolic expressions (equations and formulas) and atomic and molecular perspective (particulate level) that are presented in lecture, laboratory and via textbooks.

The chemistry courses thus become a limitation for many aspiring students who aspire to pursue STEM majors or seek careers in STEM-related fields[9]. Hence, the general chemistry sequence courses that are prerequisites for undergraduates in the STEM majors or closely allied disciplines, and that have a high student enrollment but low retention seem to be a logical target for sustained efforts to improve student academic performance[6, 10-12]. It becomes pertinent for various stakeholders involved in chemistry education to ask and address questions on how students learn chemistry and how effective are teaching methods. Specifically, are the current curricular materials addressing the needs of diverse students. [13]. Is there a way to address the needs of diverse students? Many researchers have challenged institutions and educators to find a creative way to work with students from culturally and linguistically diverse (CLD) backgrounds to ensure that students find relevance of the content with respect to cultural practices [14]. Connecting the modern scientific concepts to students everyday cultural practices can enable students to make personal connection with the content; aid in construction of ideas from everyday life experiences; and simultaneously enhance student knowledge by merging cultural practices with modern scientific concepts[15].

In addition, many researchers have asserted that students' academic performance might improve from culturally and linguistically diverse (CLD) backgrounds if chemistry educators make the effort to ensure that classroom instruction integrates students' own cultural practices[16]. The inclusion of indigenous voice in STEM education is necessary because students pursuing STEM majors to become scientists, engineers, doctors and nurses need a wide range of experiences to enrich the pool of ideas from which excellence and creative solutions to problems in their feeds are generated[17-20].

1.3. Culturally Relevant Education in Chemistry Curriculum

Nieto in 2014 defined culturally relevant education (CRE) as an approach that necessitates inclusion and authenticity[21]. Nieto emphasized that all people, especially teachers, should understand diverse cultural characteristics, experiences, and perspectives of their students for effective teaching[21]. Interconnected tenets of CRE pedagogy identified by Ladson Billings included an emphasis on (1) student learning and achievement, (2) the affirmation of students' cultural competence, and (3) the facilitation of critical consciousness that supports students' understanding and critique of inequities within educational and social institutions [22].

Students in general chemistry struggle with various concepts such as atomic structure, stoichiometry, acid-base chemistry, solutions, and chemical equilibrium. Often students are vocal about their inadequate understanding of chemistry and acknowledge their weakness and struggles with concepts. Students often resort to rote memorization of formulas and equations and can correctly answer direct questions that require regurgitation of terms and definitions. During the lecture or when using a textbook, students come across highly complex information which is disconnected from students' prior experiences and everyday lives. Though demonstrations during lecture and laboratory experimentations alleviates some of the challenges associated with learning chemistry and making sense of the process to connect the concepts. Students who are high academic achievers benefit more from such experiences. Students in the middle and bottom find these opportunities apparently interesting. As individuals with different backgrounds, students realize that the scientific phenomena are more complex than it appears.

It is hence no doubt that many students find chemistry to be abstract and challenging. As reported by researchers on student struggles with chemistry and the increase in DWF (Grade of D, Withdrawal or Failing grade), students perceive chemistry to be a discipline with a series of disconnected ideas that lack relevance to their everyday lives. In students view, chemistry is compartmentalized and is a hurdle that they need to get past to get to their majors. There is no relevance of chemistry outside the classroom or laboratory among such students[23-28]. A major reason that students arrive in the chemistry courses with the impression that understanding chemistry concepts involve memorization of equations and theories, and that all information is available only in chemistry textbooks and somewhere on the internet. The classroom lectures, laboratory experiences and curricular materials leave negative taste among students in college especially when that experience is no different from what they had experience in high school chemistry courses. It is reasonable to question if such experiences foster unhealthy students attitudes towards

STEM field especially when students find it difficult to gain any conceptual understanding and when their academic performance in chemistry courses remains dismal despite their sincere efforts to use these experiences to make any sense of chemistry.

The tenets of culturally relevant pedagogy (Student Learning and Achievement, Cultural Competence, and Socio-Political Consciousness) were adopted by this study to emerge the creation and development of culturally relevant sustaining education opportunities in chemistry concepts. This study is focused on CRCE to address the gap in the teaching and learning of chemistry. The tenants of CRE have been integrated in modules that were developed to address the cultural relevance of chemistry. Since South Dakota is a state that has a significant population of Native Americans, the modules have integrated cultural practices of Native Americans to draw student attention to how the practices of a specific group of people also find their place in chemistry. The concepts in chemistry and the cultural practices are integrated in each module to help students learn from the practices of Native American’s and at the same time reflect on the concepts and the practices in their own culture and everyday experiences. The purpose of developing student-centered inquiry-based modules was to help students gain a conceptual understanding of chemistry and see the significance of the subject from the traditional cultural standpoint.

For integrating CRCE modules in first year (first semester) large enrollment general chemistry course, five CRCE modules were developed on various topic. A list of modules and topics is provided in **Table 1.1**

Table 1.1. Modules and Topics Covered in Module.

Developed Modules 1-5	Topics Covered in Module
Module 1	Scientific method, states of matter, and measurements
Module 2	Chemical Bonding: Ionic and covalent Compounds
Module 3	Chemical Reactions: Energy, rates, and equilibrium
Module 4	Solutions, types of solutions, and properties of solutions
Module 5	Acids and Bases, and its contribution to environmental and industrial needs

The table also includes key concepts that were covered in the modules as per the syllabus of CHEM-106 which is a first semester general chemistry survey course for health sciences, agricultural sciences, and other science related majors. The overarching purpose of this study is to study the impact of CRCE through these modules on student conceptual understanding, academic performance, motivation and self-regulation, and attitudes towards the subject of chemistry using sequential exploratory research design.

The following chapter (chapter 2) includes an overview of the three fundamental characteristics of a good research: (a) the theoretical frameworks, (b) the guiding research questions, and the (c) the methodology. In CRCE study, culturally relevant education theory, constructivism and social constructivism, and Mayer's cognitive theory of multimedia learning were the theoretical frameworks that informed the study. In chapter 2, the overarching purpose to develop chemistry modules that incorporate CRE in chemistry teaching and learning and research method were addressed.

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CHAPTER TWO

THEORETICAL FRAMEWORKS FOR THE CULTURALLY RELEVANT CHEMISTRY EDUCATION

2.1. Introduction

It is extremely important for research in chemical education to be theory driven. Theories provide basis for the researcher to develop explanations and potential modifications in their approach to studies to resolve a problem. According to Abraham, theory provides a framework for research, curriculum development and evaluation and can also aid in developing effective instructional tactics and strategies[1]. Abraham asserts that research in chemical education is more powerful and useful when it is theory driven and that the curricular materials and instructional strategies should be based on the theories and be assessed by considering both the theory and also whether or not the materials works[1]. Because this project is focused on the development, piloting, implementation, and integration of CRCE modules in a three semester sequence of General, Organic and Biochemistry courses, this project and the study of the effectiveness of the CRCE modules were theory-based.

Any good research study has three fundamental characteristics – it is informed by a theoretical framework; the guiding research questions answered by the study that are in agreement with the theories; and the methodology used to answer the research questions concurring with the theoretical framework[2]. This project is informed by 3 theoretical frameworks namely (a) culturally relevant education theory, (b) constructivism and social constructivism, and (c) Mayer's cognitive theory of multimedia learning. Following section provides a brief overview of the theoretical frameworks that informed the development and the study of the effectiveness of CRCE modules.

2.2. Culturally Relevant Education (CRE) Theory

Globally, the need for a teaching force prepared to handle and address issues of pedagogy is important. CRE is a framework that recognizes the necessity of including students' cultural backgrounds, and everyday experiences in all aspects of teaching and learning[3]. CRE improves student engagement and achievement, and implementing CRE in chemistry teaching and learning could potentially impact student engagement and achievement in general chemistry [4]. CRE can be impactful for students to help them make connections between what they learn in a classroom and their own life experiences. Since the use of CRE approach involves application of cultural referents to impact student knowledge, skills, and attitudes, this framework served as the guiding force for the development and effectiveness of CRCE modules and their impact on student attitudes, conceptual understanding, motivation and self-regulation, and academic performance[5, 6]. CRE guided CRCE study which helped students to access the exact curriculum and see the relevance between what they learned in the course and that of their lives.

In CRE framework, there is the use of cultural scaffolding that make use of students culture and experiences to expand their intellectual horizon and academic achievement[7, 8].

CRE guided developed modules to incorporate relatable examples to students' daily lives. As a standard-base content connecting cultural references to chemistry concepts, CRCE modules used cultural knowledge, frames of reference, and students everyday experiences to help make learning more impactful[9, 10]. The cultural assets students bring with them to the classroom was made accessible through modules, reflecting about the students' own lives and society. With the modules, students were able learn about and develop pride in their own culture and appreciate others' cultures.

2.3. Constructivism and Social Constructivism

Constructivism is focused on the construction of knowledge by an individual wherein an individual has a central role in the learning process[11]. Theory of constructivism is about knowledge and learning which describes both what knowing is and how an individual comes to know[12]. In this case, the learner constructs the knowledge, rather than passively acquiring the information. The constructivist framework places importance on the leaner who interacts with the learning environment to develop an understanding of its features and the characteristics. The power to understand and make sense of information to construct coherent scientific knowledge resides in the hands of learner or an individual who engages both physically and mentally with the resources and the environment. Hence according to constructivism, learning and conceptual understanding is a direct outcome of an individual's efforts for the construction of knowledge during which the learner processes and adds new information to their prior or existing knowledge and conceptual framework.

Thus, the new information presented through curriculum modules and the experiences is matched against the given information and the prior knowledge to establish a meaningful connection. Such construction of knowledge through the curriculum is an active and deliberate process that does not rely on rote memorization and regurgitation. In constructive thinking, learning is greatly shaped by the contexts, views, beliefs, learner's attitudes regarding the subject, their self-efficacy, and the fundamental ideas presented to them[11, 13, 14].

Social constructivism is focused on both the social interactions and personal experiences of students that greatly influence their information processing and subsequent knowledge construction. Social constructivism originated with Vygotsky's ideas on the zone of proximal development which is essentially the gap between the existing or prior knowledge of a learner and the knowledge that a learner is capable of constructing with the help of an expert (instructor)[15, 16]. Social constructivism is a widely applicable theoretical framework for teaching, learning and curriculum development. According to social constructivism all students can benefit from their interactions with peers in the presence of a knowledgeable instructor. Collaboration via student-student and student-teacher interaction are interconnected and highly emphasized as these provide the intellectual support needed by the student to go beyond what he/she can accomplish on their own. Social constructivism is thus applicable in the context in which learning occurs, and the social and individual contexts that learners bring to their learning environment. In facilitating learning with the social constructivism framework, there is the need to incorporate the four general perspectives[17].

These four general perspectives of social constructivism to incorporate are; (a) cognitive tools perspectives which focuses on the learning of cognitive skills and strategies , (b) idea-based social constructivism which set education priorities on important concepts to expand the learner's vision and impact the learner's thinking, (c) emergent approach which affirms that social constructivism should emerge as the need arise, and (d) transactional perspectives which focuses on the relationship between the learner and the environment[17, 18].

Utilizing social constructivism in the classroom and incorporating elements of constructivism in a curriculum require active learning and engagement with the information presented. It can help students understand that learning is not a passive retrieval of information but an everyday process to generate and regenerate ideas and concepts.

2.3.1. Social Constructivism and Conceptual Understanding: The Relationship

The theories of the individual and social constructivism focus on the development of student knowledge on concepts through personal construction and social interactions. The emphasis is on one's understanding of a concept and seeking meaningful patterns and understanding anomalies by thinking critically about the information and ideas presented rather than memorizing those concepts. The transactional cognitive perspectives which focuses on the relationship between people and their environment is a characteristics that constitutes the individual engagement in learning the material[17, 19].

Learning that is centered on collaboration and interaction can help students understand and share acquired knowledge. Since individuals have different cultural perspectives, CRCE modules can help students understand concepts just like how people from other backgrounds do and gain insights into chemistry by developing a thinking process that merges culture and chemistry content. It is good to understand that social constructivism is based on the social interactions of a student in the classroom along with the student's personal critical thinking process[20]. Learning should not be isolated from the environment that students know or experience. Thus, when a mind is in operation, its owner is interacting with the environment that may include a textbook, modules, multimedia, laboratory equipment, the peers, and the instructor.

The environment and social relationships among members may change as they move from more personal to social settings in a classroom or a laboratory, which may also bring changes to the tasks assigned to the individual. Example is an individual learning from multimedia or a text that does not require social engagement and an individual learning similar content in class with peers and the instructor during collaborative activities [21].

2.3.2. Social Constructivism and Cultural Models

Integrating cultural models in chemistry classroom provides instructional or learning tools that are based on the social constructivist perspective, stressing the need for interaction among learners, and with their cultural practices in the society. Social constructivism emphasizes the importance of culture and context in understanding what occurs in society and constructing knowledge based on the understanding[21, 22]. Lave and Wenger in 1991 asserted that a society's practical knowledge is situated in relation among the learner's practice, as well as the leaner's social organization[23]. From Lave and Wenger, the practice of the community creates the desired "curriculum: which can be adopted by newcomers with legitimate peripheral process. Learning is an improvised practice: a learning curriculum unfolds in opportunities for engagement in practice. For this reason, learning should involve knowledge and practice. Also, the act of learning an activity appears to have a characteristic pattern with several strong goals for which the learner as the peripheral participants can develop a view of what exist to be learned.

The construction of knowledge is influenced by the intersubjectivity of the cultural and historical factors of the community such as ethics and values, and education[17, 18]. This enables easy understanding of new life and activities that arise within the community. Historical developments are inherited by the learner through their membership with a particular culture. Symbolic systems such as language, logic in mathematical systems are learned throughout the learner's life. These systems dictate how and what is learned[24]. The social environment that we reside in defines (constitutes) who we are, and our identities as social beings. We are social beings, embedded in various relevant social communities. At the same time, human agency creates, reproduces, and changes culture through our daily practices[25].

2.3.3. Implications of Social Constructivism in CRCE

Several relevant implications arise from the theory of social constructivism. These include, (1) importance of learner's pre-existing ideas and conceptions, (2) making guidelines for assessment that are consistent in the process of learning, and (3) development of instructional tools to make account of nature and situations, thereby helping to integrate ideas and concepts[26-29].

In chemistry education, constructivist approaches can include cognitive apprenticeships through everyday activities, reciprocal teaching, problem solving via cultural instructions, peer collaborations using anchored indigenous cultural practices, and several other methods that involve learning individually and with others (Process Oriented

Guided Inquiry Based Learning; Peer-Led Team Learning and the Science Writing Heuristic approach. This constructivist approaches are also related to many contemporary theories, most notably the developmental theories of Vygotsky and Bruner, and Bandura's social cognitive theory, which states that knowledge is derived from interaction between people and their environments and resides within cultures[30]. Vygotsky's research and theories are collectively involved in social constructivism and language development such as cognitive dialogue, the zone of proximal development, social interaction, culture and inner speech[20].

2.3.4. Vignette of social constructivism in CRCE

Following vignette demonstrates how constructivism theories (individual and social constructivism) guided the CRCE study in module development and addressing the purpose of study.

Dr. Dwamena is a college chemistry professor who has found it difficult for years when it comes to teaching chemical reactions, matter and measurement, solutions, acids and bases, and chemical bonding to his students. Previously, students have found it difficult understanding these concepts. For example, students became bored with identifying reactions - decomposition reaction, combination reaction, and acid-base reaction.

Desperate for impacting students understanding of these concepts and for changing students attitudes with chemistry topics, Dr. Dwamena decided to incorporate both individual and social constructivist paradigms in his chemistry curriculum through indigenous cultural practices when explaining these concepts to his students via modules. Instead of going through the everyday curriculum route for the general chemistry course, allowing the students to remain passive and just using the lecture notes and supplemental materials for the course, Dr. Dwamena decided to develop modules on merging various cultural practices or students' everyday activities with those concepts. Dr. Dwamena started explaining these chemistry concepts to students using some already existing cultural practices that linked to these concepts. Creating the awareness that these chemistry concepts are practical in their everyday life, and are not something new, the professor went ahead and allowed the students to share and explain with their colleagues (peers) an example of how these concepts were applied depending on their ancestral background.

An example was used by Dr. Dwamena on how scientific method approaches apply in our everyday activities, and its connection to contemporary analogous practices. Students were told to give examples in addition to examples provided in the modules. They were encouraged to state examples explicitly. Students were also asked to reflect on the modules and use the concepts and the cultural scenarios presented in the modules as guidance to generate and share their understanding of their own cultural practices and its connection to chemistry. For each module, students were encouraged to share their understanding with peers using the Learning Management System (LMS) through students' discussion posts. Since students in Dr. Dwamena's class are perhaps of a diverse cultural and educational background, each student may have something unique about their own indigenous knowledges to offer and reflect on while sharing their understanding of the concepts and principles presented in the modules.

Though this is later discussed in a separate chapter of thesis, the following examples of students' quotes show the implication of individual and social constructivism in relation to this project.

A student shared with peers during discussion of a module on the matter and measurement, about how he thought of farming right away and the use of scientific method often *for how much to plant and where to plant*? The student explained how his ancestors have had to do trial and error with rotating crops or trying to plant different crops in different soils of fields. With farming, the student shared "*they needed fertilizer, and they have had to do measurements and trial/error with how much to use and on what type of crop to grow for a particular season*". Another student shared "how people use measurements every day and even yesterday he did the online lab, so he measured out everything". Another discussed about states of matter "*each state of matter is around us at all times". "Solids are packed tight, which is made up of atoms stuck close together with no movement like ice", "a liquid could be something you drink, which has atoms that move around faster and more freely in a contained space", "gases have atoms that move all over the place and change shape, and example is water vapor*". These are all examples of student understandings based on the modules that they shared by reflecting on their individual and social experiences around them. As mentioned above, the intent to present excerpts from student discussion of modules was to highlight how the individual and social constructivist paradigms are integrated in the module development and integration in a first semester general chemistry survey course. The modules will be discussed in the later chapter in thesis.

The ideas presented thus far demonstrate the use of constructivist theories and also corresponds with Piaget's theory of cognitive development which proposes that humans cannot be given information which they will immediately understand and use; instead, humans must construct their own knowledge[20]. Once students understand the concepts through their own examples, they willingly share their understanding with peers, who in turn, share their own examples, and provide feedback to the peers in a less formal manner through online discussion of modules.

Students were later assessed by Dr. Dwamena through quizzes and exams. Their attitudes, and motivation and self-regulation toward chemistry were also evaluated through some survey questions. By engaging with modules, discussion posts, response to survey questions, and answers to quizzes and exams, students perhaps gain a sense of the ownership of the modules which now involves their own experiences and interactions merging with the concepts and principles of chemistry . The intersubjectivity the students experience through the reflection on their cultural and everyday practices and sharing these with others allows students to extend their understanding of chemistry. In doing so, students frequently refer to their own cultures, interests, and historical backgrounds that shape their understanding of the subject matter and its relevance in their life. The constructivist framework guided Dr. Dwamena in achieving his goal of helping students understand the concept of matter and measurement, chemical reactions, chemical bonding, etc. With this, the knowledge is theorized as being developed by the learner with a socially relevant and scientific conceptually coherent content[2].

2.4. Mayer's cognitive theory of multimedia learning

A fundamental hypothesis underlying research on multimedia learning is that multimedia instructional content designed based on the workings of a student mind are more likely to lead to a meaningful learning [31]. Mayer's cognitive theory of multimedia learning considers the workings of brain in terms of words, pictures, and auditory information. Hence the interpretation and integration of information presented through a multimedia presentation involves processing of words, pictures, and auditory concepts not in a mutually exclusive fashion but rather, these elements are selected and organized dynamically to generate logical mental constructs. According to the cognitive theory of multimedia learning "people learn more deeply from words and pictures than from words alone leading to the provision of coherent verbal, and pictorial concepts that guides the student in selecting relevant answers to questions" [31].

The cognitive theory specifies five cognitive processes in multimedia learning: (1) selecting relevant words from the presented text or narration, (2) selecting relevant images from the presented illustrations, (3) organizing the selected words into a coherent verbal representation, (4) organizing selected images into a coherent pictorial representation, and (5) integrating the pictorial and verbal representations with the prior knowledge.

2.4.1. Mayer's cognitive theory of multimedia learning in CRCE

The use of multimedia design and theory to convey module contexts involve a focus on how students learn. CRCE Modules for this project were developed as texts and videos guided by Mayer's theory of multimedia learning. This focus on the theory of multimedia learning aimed at enabling students to process culturally relevant education in chemistry concepts with specific examples for students in a general chemistry survey course. To foster student conceptual understanding so that students connect and use representations in modules to develop their own mental representations, the modules embedded such references into texts and accompanying videos. Mayer's theory of multimedia learning also emphasizes the importance of demonstrating content in a simple and engaging way to promote successful transfer of knowledge when new concept is integrated with prior scientific cultural knowledge[32, 33]. These considerations served as a basis of the CRCE module development, implementation, and integration which are discussed in later chapters.

2.5. An Introduction to Purpose, Research Questions and Methods as Informed by Theory

2.5.1. Purpose of CRCE in General Chemistry

The overarching purpose of this study was to develop chemistry modules that incorporate CRE in chemistry teaching and learning. The modules developed for the CRCE project aimed at helping students make personal connections between chemistry content and cultural practices as measured by:

a) the impact of the CRCE modules on student academic performance

b) the impact of modules on student conceptual understanding,

c) role of modules in addressing the student motivation, and attitudes toward the subject chemistry pre and post implementation of the modules.

The study made use of constructivist modules to connect cultural references specifically those of Native American tribes, and student’s own life experiences and the connections of these two with the various concepts taught in a general chemistry course at the South Dakota State University.

2.5.2. Research Questions for CRCE

Studies in chemical education focus on developing and addressing a research question related to a topic. As easy as this might sound, devising a question that can rigorously investigate, and convincingly address a problem in chemistry education can be challenging for even experienced researchers[34]. The five components of a good question as highlighted by Bunce were considered for this project[34].

The components are 1) are the questions worth asking? 2) are the questions feasible? 3) who are the participants? 4) how are they going to be investigated? and 5) what will be the key findings after the study?

According to Bunce, the first question that researcher needs to ask is what they want to know. This component guided the decision- to know the impact of CRCE on student's academic performance, conceptual understanding, motivation and self-regulation, and attitudes toward the subject chemistry. The second and third components - "*Are the questions feasible? Who are my participants*? helped in focusing on undergraduate students enrolled in a general chemistry survey course that is very diverse with respect to student backgrounds and has a large enrollment both in the fall and spring semesters. The course is mainly intended for students who may have very little background in high school chemistry or who had have considerable high school chemistry experience. The chemistry survey course is a gatekeeper for students interested in pursuing health sciences, agricultural sciences, and other science related majors at South Dakota State University.

The fourth component of a research question is "how is it going to be investigated"? For example, the how will be the impact of CRCE (on student academic performance, conceptual understanding, attitudes as well motivation and self-regulation of undergraduate students enrolled in general chemistry course) be measured and evaluated? The latter guided the thought on deciding the research methods and appropriate surveys and tools to address what needs to be known to answer/address the research problem to address the key findings of the study (fifth question). These step-by-step processes evolved with the literature review on theoretical frameworks and the CRCE modules. The following research questions were developed and refined for CRCE in relation to the modules:

1. What is the impact of developed CRCE modules on student academic performance?
2. Do the CRCE modules impact student conceptual understanding and their awareness of chemistry and culture?
3. Do the CRCE modules impact (a) student motivation and self-regulation, and (b) student attitudes towards the subject chemistry?

To be certain that student performance is an outcome of CRCE modules, few things were addressed early in the planning stage of this project. First the instructor for the course was same for all three semesters. This addressed issues that may have arisen due to changes in teaching style. Second the CRCE modules were implemented in three successive stages a) piloting b) implementation and c) integration stage. This helped with systematically collecting both qualitative and quantitative data from students enrolled in the general chemistry course. Each stage is discussed as a separate chapter and data collection, analysis with results from each stage are discussed separately for research questions to address the overarching purpose of the impact of CRCE on cognitive and affective changes in students.

2.5.3. Research Methods

2.5.3.1. Rationale for the choice of Sequential Exploratory Design

To decide which methodologies will best fit the research questions, the four key decisions proposed by Creswell in the field of mixed method study was followed [35]. These include (1) the approaches to data collection to answer the proposed research questions, (2) the research approach among the qualitative and quantitative methods that has the dominant priority, (3) ways data collection and analysis will be integrated for both approaches and (4) a consideration of the theoretical framework to guide the study and if they serve to inform the study purpose and methods.

After going through these components, the research questions for CRCE studies were checked again. The review of literature pointed to a gap in the curriculum for the Culturally Relevant Chemistry Education. Specifically, the fact that classroom instruction and current textbooks do not embed a cultural framework or reference for the teaching and learning of chemistry. A study from Nigeria discussed the use of such curriculum but did not provide any exemplary modules for integrating CRCE with students in general chemistry at South Dakota State University[36]. This served as a motivation for the development of such modules; the purpose of study, and development of the research questions focused on the culturally relevant chemistry education modules to impact student conceptual understanding and academic performance[7, 10].

Due to the lack of studies in chemistry education and the literature gap in this area, the research questions required the use of a sequential exploratory design for data collection and analysis, which involves the mixing of two methods, that is the qualitative and quantitative methods of data collection and analysis in a single study[37]. The flowchart below depicts a general sequential exploratory approach (**Figure 2.1**).

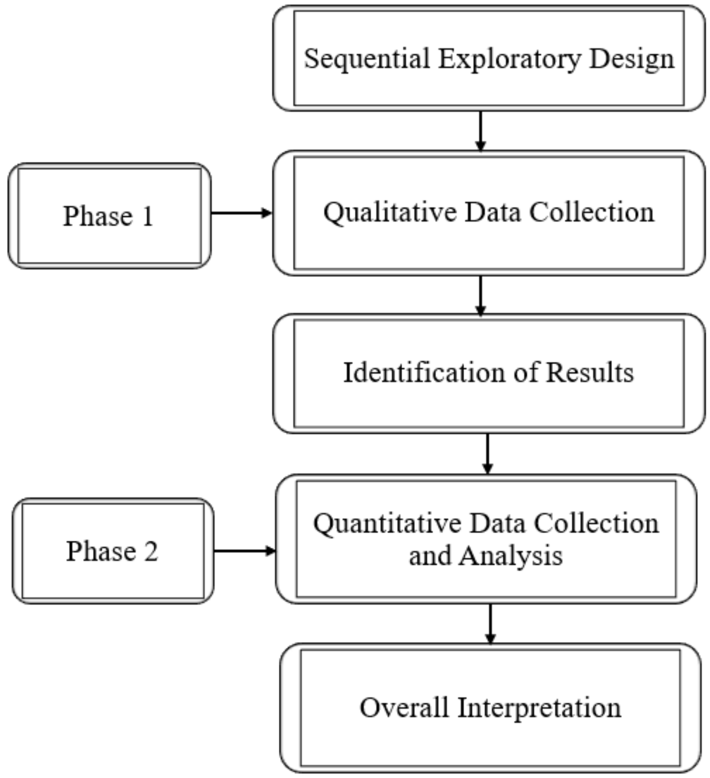

Figure 2.1. A Sequential Exploratory Design

The approach helped to balance the inherent strengths and weakness of the methodology, and lead to a more interpretable and valid outcomes that either approach could have provided alone[37]. Both methodologies were dominant. Qualitative research approach used in the study involved student's discussion posts, interviews, and series of survey instruments used in a pre-test and post-test format. Results were analyzed quantitatively to explore the extent of students' motivation and self-regulation, attitudes as well as their conceptual understanding. Qualitative analysis flowed into and shaped the quantitative data collection which comprised of quizzes, and exams.

The quantitative methodology followed several parametric and non-parametric measures, reflecting the impact of CRCE modules on student's academic performance. The aspects specific to this project are described in separate chapters for simplicity and ease of presentation.

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CHAPTER THREE

DEVELOPMENT OF MODULES FOCUSED ON CULTURALLY RELEVANT CHEMISTRY EDUCATION

3.1. Development of CRCE Modules

A developed educational system that is supportive of diverse cultures is imperative considering rapid and sustained globalization[1]. In the United States, globalization accounts for three phenomenon: (1) the inclusion of non-mainstream American students in mainstream public schools, (2) the increase in first and second generation immigrant students estimated to be 30% in 2015, and (3) the national standardization of education permeating all public schools[2]. Globalization entails systemic changes required of educational institutions to address the needs of students with multiple cultural backgrounds.

Incorporating and institutionalizing students cultural practices, that allow students to appreciate the self-investment relating to the discovery of new knowledge is perceived to be a better way to impact students motivation, and interest[3-7]. Most culturally relevant efforts within STEM education have addressed approaches individual instructors can take within their own classrooms to impact students understanding, interest, and ability to engage in content area discourses, and higher test scores. This includes: bringing culturally relevant examples into specific classrooms[8-11].

However in the field of chemistry education, the problem is that, little is known about modules that make use of constructivist methods connecting students' own cultural references with the chemistry concepts, and also engaging students critical reflection about their own lives and societies[12, 13]. Also, most of our university chemistry departments do not facilitate students' cultural competence, in helping students recognize and honor their own cultural beliefs and practices in our modern chemistry concepts [14, 15].

To address this problem, this study makes use of culturally relevant inquiry-based modules that foster the use of constructivist methods connecting students' cultural references with the chemistry concepts, and also engages students critical reflection about their own lives and societies to impact their academic performance, conceptual understanding, motivation and self-regulation, and attitudes towards the subject chemistry. The development of CRCE focused modules was an intensive component of this project that spanned a period of ~5 months to develop five modules focused on various components of general chemistry.

The development of modules involved the process of an extensive literature review, and a deeper look at the current chemistry content offered in the general chemistry survey course. To develop the CRCE modules several current everyday applications were explored that connect to the various chemistry concepts. Based on the review of the syllabus, lecture notes and slides from prior course offerings, the content of the general chemistry course was found to be appropriately structured (**Appendix 1**). However, the content lacked several examples, analogies, and practices that could help students make personal connections between the chemistry content and their individual cultural practices in the general chemistry[16]. Another important aspect for the development of the CRCE modules was the inclusion of Native American practices in the modules. The practices included in the modules were based on extensive review of the literature and texts that focused on the stories of Native Americans[17-23].

Both slides and the textbook provided some common everyday applications. For instance, after going through the study materials that include the course text, and the PowerPoint Slides on acids and bases, the text and the slides were found to contain terminologies and description of acids and bases. From the text and slides, commons examples of acids and bases were sulfuric acid, phosphoric acid, magnesium hydroxide, and ammonia. Students were taught how to maintain the pH of blood and other fluids within narrow limits which it can be accomplished using buffers. Also, when students were studying the concept of chemical reactions, the downward flow of water was used to explain to students how lower energy tend to undergo spontaneous reaction. What the text lacks is inclusion of everyday experiences with respect to cultural connections. Mainly the examples relate to the practices of dominant groups. Also, the text does not relate to students with respect to connecting how the chemistry perhaps connect to their own life and culture. There is no mention of traditional practices of a group and how these practices involved extensive application of chemistry, even if a group of people in a certain region were unaware they were using chemistry, their practices were rooted in the applications of the principles of sciences such as chemistry.

The text content, literature, and American Chemical Society exams institute chemistry anchoring concept content map served as the bases for developing modules on matter and measurement, chemical bonding, chemical reactions, solutions, and acids and bases[16, 24, 25]. These concepts are considered fundamental to the first-year general chemistry survey course (**Figure 3.1**).

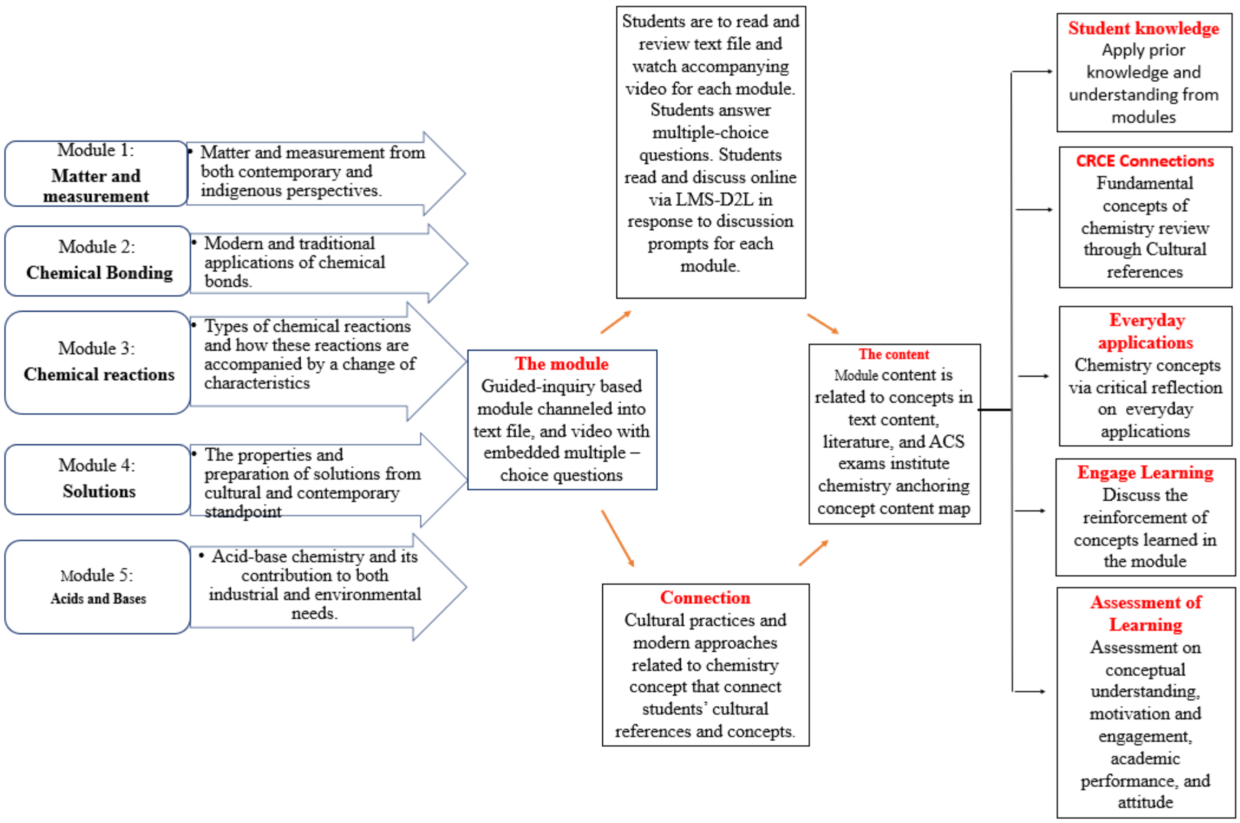

Figure 3.1. Content Map Structure of Modules

Introducing modules that examine traditional indigenous practices in detail through a chemistry perspective is crucial for student conceptual understanding and help student see the connection between traditions and science[26]. For modules focused on culturally relevant chemistry education, it was important that examples and descriptions used in these modules capture both the examples of cultural practices and the content presented in terms of the modern science. The goal was that students can relate these modules to the content presented via their textbook and the material covered in the lecture component of the general chemistry. The focus was also to find ways to help diverse students in the course engage with modules so that students find modules beneficial for their learning with respect to their understanding of the concepts, awareness of the applications of chemistry in their own experiences, and address the issues of student perception towards chemistry being a difficult subject.

Further, the modules were specifically focused on the practices of cultural practices of Native Americans. The rich history, traditions and culture of the Native Americans and the emphasis on cultural practices of the population of South Dakota was considered to be of value to enable personal and subject-matter connections for the first year (and first semester) students in the general chemistry. South Dakota State University is in the Brookings county of South Dakota and is close to Native American reservations.

The state of South Dakota has the third highest proportion of Native Americans that closely follows the states of New Mexico and Alaska. South Dakota has nine reservations and designated tribal land areas - more than any other state. Five of the state's counties (Corson, Dewey, Oglala, Lakota, Ziebach, and Todd counties), lie entirely within Indian reservations[27-29]. The state of South Dakota is a home to more than 75,000 Native Americans. A vast number of Native Americans live on reservations. Note that an Indian reservation is a legally designated area of land that is managed by a federally recognized Indian tribe.

There are about 326 Indian reservations in the United States that are associated with a particular Native American nation and nine such reservations are in South Dakota (Crow Creek Flandreau Santee Sioux, Yankton, Rosebud, Lake Traverse, Standing Rock, Lower Brule, Pine Ridge, and the Cheyenne River Reservations).

Despite a push for diversity and inclusion, South Dakota State University (SDSU) is lacking resources and tools that make higher education especially STEM majors welcoming for a diverse student population including first generation college students and

Native Americans. According to the College Factual, SDSU ranks 549 out of 1715 colleges and universities in USA and has a diversity score of 70 (out of 100) which means SDSU wants to attract a diverse student population and is striving to achieve this goal[30 31].

A review of student demographics, ACT, SAT scores and student retention shows that SDSU faces the same crisis that many high education institutions are dealing with regarding four-year student graduation rates and student retention. A summary of student diversity at SDSU is provided in **Table 3.1**.

Table 3.1. Student Diversity in SDSU[31].

Student Group/Diversity	Percentage of Undergraduate Students
White	86.4%
Non-Resident Alien	3.80%
Hispanic/Latino	2.70%
Black or African American	2.20%
Asian	1.10%
American Indian or Alaska Native	1.00%
Native Hawaiian or Other Pacific Islander	0.100%
Ethnicity Unknown	2.80%

SDSU has an acceptance rate of 91% with 53% students who are accepted as being females. Out of 8425 full time undergraduates at SDSU, about 7.6% students were reported to be minority students. In addition, the SDSU overall diversity rank was 867 out of 2475, and 49.8% of the students attending SDSU were from within the state of South Dakota. Student retention is a huge issue at SDSU. Though the Freshmen retention rate of SDSU is 77% the four-year graduation rate is at 30%. The ACT composite percentile scores for college admitted students ranged between 20 and 26 (out of 36). Only 3% students submitted SAT scores that ranged between 480-630 for the SAT Reading and Writing Scores, and between 500-630 for SAT Math Scores (both out of 800).

The demographic data shows that about half of the student population is from South Dakota out of which ~86 percent are white students, and the rest of students is a diverse group comprising of 1% Native American students. The data shows that SDSU can attract students, however student retention and students majoring in STEM areas remains a challenge. This is consistent with the national trend where fewer students leave with a STEM degree from the college[32]. At institutions nationwide, chemistry courses are known to be a barrier to success among first- and second-year STEM majors. A consequence of low success rates in high impact gateway courses like chemistry is that it affects student retention in STEM areas[33-36].

The decision to apply cultural references specifically those of Native American tribes, and life experiences with these concepts was made to reach out to both the majority students and specifically the first generation and Native American college students taking a chemistry course as a prerequisite for their majors. Though the cultural references were specifically those of Native Americans, conscious efforts were made in writing modules for student assessment of knowledge to ensure that the modules content and examples therein applied to all cultures and everyday lives irrespective of the student's geographical background.

The CRCE modules mainly focused on the conceptual understanding through examples of inquiry, enhancing communication skill and cooperative learning among students and emphasized the socio-scientific decision making[37]. For students who took part in the CRCE study, this was their first contact with a module approach design. At the piloting stage of study, only two modules were developed to assess its impact on student academic performance, conceptual understanding, motivation and self-regulation, and attitudes toward the subject chemistry. Overall, 5 modules were developed as texts and videos (**Appendices 2-6**). For the assessment of student knowledge, multiple-choice questions were included in each module. These questions were embedded into each video file. The videos were made available to students through Desire 2 Learn (D2L), a learning management system. An overview of each module is illustrated below with the detailed modules in Appendix.

3.1.1. Module 1. The Practice of Scientific Method: Merging the Native Americans View and a Contemporary Perspective

Module 1 focused on the introductory topic of measurement from both contemporary and indigenous perspectives. The module explained how the Native American's used scientific methods or its components via examples. The module also included an overview of the modern approach to gathering of scientific information using experiments and observations – namely the scientific method. Module 1 highlighted various scientific steps for making predictions. After emphasizing on the importance of scientific methods, the modules elaborated how Native Americans were applying the theories of states of matter, as well as measurements in their everyday activities. For example, a real-life application of asphalt was used to explain to students the concept of physical change as stated.

Asphalt (a semi-solid or solid) was used by the tribes at the east of the Missouri river as a water-proofing agent[18]*. Solid asphalts are closely packed and have fixed shape and volume. Asphalt undergoes a physical change during its formation. Heating of the dry asphalt result in changes in the state of the matter (solid to liquid state).*

Ancient methods of measurement were also used to explain to students how they make use of familiar objects for measurement every day just like how measurement takes place in laboratory and in daily experiences. Modules also provide explanation on how measurements by the Native Americans made use of the distance of a step, length of foot, and width of fingers. Native American practice of the chinampas technique to help increase crop productivity was used to explain to students the concept of density. This was linked to our modern laboratory experimentation related to finding density using ruler and geometry, and water displacement method. Details of module 1 can be found in **Appendix 2**.

3.1.2. Module 2. The modern and traditional applications of chemical bonds

Module 2 discussed the various properties of atoms before diving into chemical bonding. Module used how life has evolved to depend on salts and connected it to ionic bonding in compounds (**Appendix 3**). The concept of ionic bonding was explained by including the various applications of salts at home (cooking). Module also gave examples of several historical and modern applications of ionic bonding (electroplating). The examples of shampoo and conditioners were used to explain to students the concept of chemical bonding.

For example, hair conditioner made with Jojoba seeds was used by American Indians living in what is now Southern Arizona. Currently, it is one of the active ingredients used in many modern shampoos and hair conditioners. Jojoba is rich in vitamins, copper, zinc, selenium, and iodine. The ionic bonding-based mechanism of action is that hair conditioners usually contain cationic surfactants, and the outermost layer of a hair follicle which is called the cuticle is composed largely of keratin[38, 39]. Details of module 2 can be found in **Appendix 3**.

3.1.3. Module 3. Chemical Reactions: Energy, Rate and Equilibrium among Native Americans

This module focused on the types of chemical reactions and how reactions are accompanied by a change of physical and chemical characteristics. Module 3 explained to students the Native Americans applications of chemical reactions. For example, the fire making process involved the striking of two hard pieces of stones, and the rubbing of two wood pieces together for oxidation reaction to occur during the Milpa process which resulted in the release of heat (an exothermic reaction). The examples of the conservation of energy during its transfer from the surroundings into the system were used to explain energy exchanged in chemical processes during an endothermic reaction. Traditional application of storing energy as well the disorderliness of a system were used to explain the modern concept of enthalpy and entropy of a system (**Appendix 4**).

3.1.4. Module 4. Study of solutions: From Native American Experience to Modern times

Module 4 focused on the properties and preparation of solutions and included presentation of solutions from cultural and contemporary standpoint. For example, the application of a solution called Adobe (a mixture of clay and water used as a building material by the American Indians of pre-Inca Peru) was explained in detail[18]. Adobe was either applied wet, serving the function as mortar or plaster, or it was mixed with fiber and dried to form bricks.

The mixing of the clay and water is an example of solution. The mortar formed is by solid-liquid interaction. Furthermore, module 4 showed applications of the colligative property by the Native Americans using dogbane (a perennial plant). Native Americans used dogbane in treating dropsy, a condition characterized by an accumulation of fluid in body tissue. This related to the osmotic pressure of a solution which is the minimum amount of pressure required to prevent water from flowing into the system across a semipermeable membrane (**Appendix 5**).

3.1.5. Module 5. Acid-base chemistry from a cultural standpoint

Module 5 focused on the use of acid-base chemistry. It explained to students how acids and bases contribute to both the industrial needs and the environment. This module provided wide applications of acids and bases, ranging from their use in the laboratory and to the kitchen. Examples of substances containing acids included foods such as vinegar, limes, and lemons. The production of vinegar, an acetic acid, which is a carboxylic acid (containing COOH group) was used as to explain acids. For example:

The primary acid in vinegar is acetic acid which is generally produced because of fermentation following an alcoholic fermentation. These alcohol fermentations generally start with fruits or grains. The conversion of ethanol (CH_3CH_2OH) and oxygen (O_2) to acetic acid (CH_3COOH) takes place by the following reaction:

$$CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$$

Some examples of this cycle are conversion of grapes to wine vinegar; apples to hard cider; hard cider to apple cider and apple cider to vinegar, or grain to malt (sprouted fermented grain), to vinegar. Vinegar can be made from wild yeasts and organisms present in the *environment by fermentation or through the inoculation of a mother culture such as you would find in raw apple cider vinegar.*

Through this module, students also learned about common bases in substances such as baking soda and detergents. The module illustrated several reactions involving acids and bases (**Appendix 6**).

Modules after development went through series of reviews for clarification, and to make sure that the content was understandable. In the next chapter (**Chapter 4**), the chapter addresses the measurement of CRCE modules on student's academic performance, conceptual understanding, motivation and self-regulation, and attitudes towards the subject chemistry.

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CHAPTER FOUR

ASSESSMENT OF CRCE MODULES IMPACT USING MEASURING INSTRUMENTS

4.1. Introduction

Demonstration of students' academic performance, conceptual understanding, motivation and self-regulation as well as attitudes was critical for the CRCE modules. This was essential to see to it that the modules were achieving its purpose. From Previous chapter (Chapter 2), the overarching purpose of CRE study was to develop chemistry modules that incorporate CRE in chemistry teaching and learning, and made use of constructivist modules to connect cultural references specifically those of Native American tribes, and student's own life experiences and the connections of these two with the various concepts taught in a general chemistry course.

The research questions were (1) what is the impact of developed CRCE modules on student academic performance? (2) do the CRCE modules impact student conceptual understanding and their awareness of chemistry and culture? and (3) Do the CRCE modules impact (a) student motivation and self-regulation, and (b) student attitudes towards the subject chemistry? These research questions required the use of a sequential exploratory design for data collection and analysis, which involves the mixing of two methods, that is the qualitative and quantitative methods of data collection and analysis in a single study[1].

Mode of data collection for research question 1 was pre and post quizzes and exams. The quantitative methodology followed several parametric and non-parametric measures, reflecting the impact of CRCE modules on student's academic performance. Data collection for research question 2 involved student's discussion posts, and interviews. To answer research question 3, series of survey instruments used in a pre-test and post-test format were used and results were analyzed quantitatively to explore the extent of students' motivation and self-regulation as well as attitude towards the subject chemistry. The aspects describing how each instrument was used to answer each research question is presented below.

4.2. CRCE on Students' Academic Performance

General chemistry is a foundational course required for STEM undergraduate majors, suggesting its importance for student's advancement in college. Yet many studies have highlighted the fact that college level general chemistry is often a challenging for students[2]. The rate at which students receive a grade of D or F in general chemistry has been reported to be over 50% versus 33.4% for other STEM courses[3, 4]. Literature shows that chemistry is important prerequisite course for STEM majors, yet student performance and conceptual understanding remain an issue for students taking first and second year general chemistry courses. The rates of D, W, F is higher in these courses and can be attributed to several factors such as teaching and learning, curricular materials used for teaching and lack of opportunities for student engagement and connection with the chemistry content[5]. To help overcome the challenge of the gap of curriculum materials, the development and study of the CRCE modules also focused on the impact of these modules on undergraduate students' academic performance during the stages of piloting, implementation and integration of CRCE modules spanning over summer, fall and spring semesters. Three standardized assessments were used to study the impact of CRCE modules on student academic performance. These include:

a) Misconceptions-oriented Standards-based Assessment Resources for Teachers (MOSART) test.
b) California standard test (CAST)
c) American Chemical Society's first semester general chemistry exam from the three semesters General, Organic and Biochemistry sequence (year 2014 version A and B also called as the grey form and the yellow form).

Measurement of student performance from one test can lead to some ambiguity on the actual effectiveness of an intervention. However, three standardized tests that are based on similar content that was covered within the general chemistry survey course were considered to be more robust to triangulate any evidence that may emerge from the quantitative data from these sources. In addition to these standardized tests, pre and post-tests (online quizzes) related to each module were administered to students to gather quantitative data related to material presented in the five modules. It was ascertained that the assessment questions in various standardized and non-standardized assessments were directly from the content covered in the modules and the topics covered in the general chemistry course.

4.2.1. A brief description of MOSART Test

Misconceptions-oriented Standards-based Assessment Resources for Teachers (MOSART) test was used to assess student understanding of the concepts from module and the topics covered in general chemistry survey course. MOSART has a set of 22 multiple-choice items focused on fundamentals in chemistry. CRCE study made use of MOSART instrument to probe for any conceptual shift among students pre- and post CRCE modules implementation (**Appendix 7**).

4.2.2. A brief description of California standard test (CAST)

The second assessment tool used in CRCE study was California standard test (CAST). The criteria for selecting CAST instrument is that the questions adequately cover a selection of academic content standards assessed on the chemistry content and presents a variety of ways standards can be assessed (**Appendix 8**). The test questions are taken from the chemistry standards test. All questions have been validated[6]. The 75 multiple-choice questions from CAST are categorized under investigation and experimentation, atomic and molecular structure, chemical bonds, chemical reactions, kinetics, and conservation of matter. CAST was also used pre- and post CRCE modules during the various stages of CRCE[6].

4.2.3. A brief description of American Chemical Society's General Chemistry Test

The third standard assessment tool used was the American Chemical Society (ACS) standardized exams. The criteria for selecting the exams was its uniqueness as a nationally normed exams for most chemistry courses as well as its ability to measure the content knowledge of students after taken the modules (**Assessment tool not available in Appendix due to ACS protocols**). ACS exams was intended to be administered at the end of the Fall 2019 and Spring 2020 semesters, but due to the pandemic, the instrument was only administered at the end of the Fall semester. The exam version that was used was the

2014 ACS general chemistry exam that has 60 multiple-choice questions focused on the first semester of a typical general, organic and biochemistry sequence courses offered in a US institution. The 60 questions include several topics covered in general chemistry. Because the chemistry topics and concepts are cumulative in nature, it is important for students to understand concepts and ideas presented in each chapter (also in the modules) to be able to answer questions related to various topics in this standardized exam. The exam has two versions form A and B and the questions in both forms are exactly same. The order of questions is changed for each version (also called yellow and grey forms).

Administration of all standard assessment tools was done through the Learning Management System D2L as a timed activity with the use of Responds Lockdown Browser. The ACS exams was administered as the final exam and followed the ACS guidelines for the administration of the exams in person.

4.2.4. Additional Assessments to measure student academic performance

In addition, four additional exams questions set by the professor in charge of the course were used to assess students' academic performance in the course. These exams covered topics during the semester and integrated concepts from CRCE modules. The exams called hour exams were used to measure systematic change in student performance during the semesters the modules were implemented (**Appendix 9**). These multiple-choice questions cover concepts introduced to students within the course. All exams were administered in a secured, proctored environment, except in other semesters that the course was conducted online (summer semester and part of spring semester due to the COVID pandemic).

A pre and post CRCE module quiz was also developed for each module. The quiz had 50 multiple-choice questions for assessing the direct impact of modules on student knowledge. All modules and quizzes were reviewed based on the appropriateness of the content and approved by the professor in charge of the course for scientific accuracy and the validity of questions (**Appendix 10**).

4.3. CRCE on Conceptual Understanding and Cultural Awareness through Discussion Prompts

When it comes to conceptual understanding in chemistry, it has been arguably generalized rather than being specific[7]. Studies have also established that the conceptual foundations of chemistry are not as robust for students as compared to their numerical problem solving abilities [7]. The conceptual understanding is mostly understood relative to standard algorithmic problem solving approaches [8-11]. To address student conceptual understanding the modules also involved discussion prompts. Discussion prompts were included in each module to allow students opportunity to share their understanding informally yet with a focus on concepts presented in the CRCE modules. (**Appendix 11**). Students were provided modules as video and text-files that were shared in the D2L-LMS and students were invited to participate in the discussion.

After having an opportunity to review the text and the video-based modules, students were asked to respond to prompts for each module and read and comment on the posts of their peers. Students responses to discussion prompts for each module were analyzed to determine the impact of CRCE modules on students conceptual understanding based on correctness and frequencies of responses which is described in later chapters.

4.4. Students Ability to Transfer knowledge from CRCE Modules: Semi-structured Qualitative Interviews

A context-based learning such as cultural references could maximize students' involvement in their scientific learning process[12]. To assess student's ability to transfer and incorporate their newly acquired scientific knowledge from modules, qualitative student interviews were also conducted. A semi-structured interview protocol was used to investigate students ability to transfer knowledge from the modules at the end of the Fall and Spring semesters (**Appendix 12**).The interview protocol included questions on student background and preparation in chemistry, resources in curriculum that student see to be beneficial, and student understanding of the traditional practices and the knowledge in chemistry.

4.5. Student's motivation for learning chemistry through CRCE modules

Students motivation and self-regulation are important aspects that influence the engagement of students in the learning process[13]. An important aim of chemistry education is to empower students by nurturing the belief that they can succeed in learning chemistry, and cultivate the adaptive learning strategies required to bring about the success[14]. Self-regulation defines students' metacognitive strategies (such as the student using appropriate skills and strategies to solve a problem), while motivation affect students' willingness and desire to engage in the learning process[15].

Motivation and self-regulation are positively correlated – students with high motivation in learning tend to utilize efficient self-regulation skills in learning the assigned tasks[16]. Also, students' motivational beliefs and self-regulation ability in the first year of college may directly affect their performance and adaptation in majoring in any field of science. For example, first year undergraduate students' perceptions of learning chemistry (involving use of CRCE modules) may influence their decision to pursue a college major and a job in the field of science. However, literature review revealed a gap in the lack of studies on students' motivational beliefs and self-regulation with respect to the CRCE development and implementation. Since there is lack of literature and curriculum on CRCE, it was deemed essential to study the impact of the use of CRCE on student motivation and self-regulation pre and post implementation of the CRCE modules.

Also, since students find chemistry to be a difficult subject and find the concepts difficult to comprehend, it became important to understand the role played by the CRCE modules towards addressing these affective traits of learners. It was hypothesized that the use of CRCE may impact student motivation and self-regulation in the study of chemistry.

A validated survey was used to collect data on student motivation and self-regulation. Students' Adaptive Learning Engagement in Science (SALES) questionnaire was used to measure the outstanding factors relating to the motivation and self-regulation of the undergraduate student enrolled during the stages in CRCE study (**Appendix 13**). The 32 items in SALES survey are grouped under 4 components relating to student motivation with each component comprising of 8 items. The first component is Learning Goal Orientation (LGO), which analyzes the extent to which the student perceives him/herself to be participating in the assigned chemistry task for the purpose of learning, understanding, and mastering the concepts as well as the skills [13].

Task value which is the second component involves the degree to which the student perceives the chemistry learning tasks in relation to his or her utility, interest, as well as importance. The third component is self-efficacy which assesses the degree of students confidence, and believes in their capabilities in successfully performing the assigned tasks [13]. The last is self-regulation where the students meta-cognitively, motivationally, and behaviorally participate in the learning process [17]. This also explains the degree to which the student regulates and controls efforts in the chemistry content learning. These components also contribute towards students adaptive learning and engagement in the course.

The 32 items correspond to the four scales measured on a 5-point Likert scale, with the scores ranging from 1= strongly disagree to 5 = strongly agree. Means of administration throughout the study was via a Learning System Management (LMS) and took about 15 minutes for the students to complete at the beginning of the semesters. Same items and scales in the questionnaire were retained and administered at the end of the semesters.

4.6. Why focus on students attitudes for the effectiveness of the CRCE modules?

The term “attitude” falls within the scope of “scientific literacy”, and plays a key role in science education[18]. Having a positive attitude towards learning a subject is one of the representations of a students’ subject literacy[18]. Several science and chemistry educators have highlighted that noncognitive factors like interest, values, and attitudes as important components of science literacy. The American Association for the Advancement of Science attests that for a curriculum to be considered as promoting scientific literacy, it is required that students pursuing such a curriculum should acquire knowledge, skills, and attitudes related to their experience[19].

The study on CRCE modules investigated students' attitudes towards learning chemistry because it is believed the last thing any chemistry educator would like to see even if a student shows an improvement in academic performance in chemistry is to perceive a) chemistry as boring, dangerous, depressing, unpleasant and b) deliberately choosing not to enroll in future chemistry courses for their majors because of these perceptions. The courses may not be required, and student views of chemistry may impact their choice of taking a next level chemistry course.

Despite a body of research depicting the efforts of research community to gather evidence on the effectiveness of a) the inquiry-based learning[20-22], b) problem solving[23-25], c) hand-on activities[26-28], and d) real-world contexts to engage students and increase student enthusiasm of doing chemistry or science in general[29-34], there is a lack of studies that show the connection between cultural reference in the curriculum and its impact on student attitudes towards the subject of chemistry. Hence it is important to study impact of CRCE developed modules on student's attitudes to draw connections between the CRCE modules itself and perhaps its impact on attitude.

4.6.1. Students' attitudes towards the subject chemistry

The purpose of developing the CRCE modules was also to address the affective aspect of student attitudes towards the subject of chemistry. Attitude toward the Subject of Chemistry Inventory (ASCI) and Colorado Learning Attitudes about science survey (CLASS-Chem) surveys were used for assessing impact of modules on students' attitudes toward the subject of chemistry. To determine whether the efforts put in developing CRCE modules were successful and that the structure and instructions for using the modules were addressing the purpose , it was essential to use a valid, reliable, and easy to finish instrument to examine students affective view regarding chemistry as a body of knowledge or skills.

Another criterion for selection was to get an instrument that will provide a functionally useful assessment of student attitudes within little administrative time.

The selection criteria for the use of these instruments involved a careful consideration of the type of information that was needed to understand the affective contribution of the CRCE modules towards student conceptual understanding and academic performance. Though in this study the treated as separate research questions, the modules may have an impact on student attitudes and these attitudes may also further relate to student conceptual understanding and performance pre- and post-implementation of the modules. It was hypothesized that student attitudes may indicate a shift towards the subject of chemistry post-implementation of the CRCE modules. A brief description of each instrument (ASCI and CLASS-Chemistry Survey) is provided as follows.

4.6.2. Attitude toward the Subject of Chemistry Inventory (ASCI) Survey

The ASCI instrument used for this assessment is designed in the format of a semantic differential where students position themselves on a seven-point scale between two polar objectives, in reference to how they feel about “chemistry” which is the attitude object. ASCI is specifically designed to focus on the student attitudes. The survey design has the attitude object “CHEMISTRY” written boldly at the top of the page (**Appendix 14)**.

In ASCI, the adjectives and choices are placed on the same line. To avoid a bias and help respondents to think independently, some adjective pairs are categorized with the "positive" adjective on the left and right[35, 36]. Inventory adjectives are positioned at the ends of each line, and the word "middle" is labelled down the page above selection 4. Inventory instructions are brief and understandable for students to complete the survey within a few minutes. The ASCI survey is made up of 20 items used to measure the attributes of attitude. Items are grouped under 3 distinct factors (Interest and Utility, Anxiety, and Intellectual accessibility, and 2 items (Fear and Emotional Satisfaction). For factor Interest and Utility, the adjective pairs were worthwhile-useless, worthless-beneficial, good-bad, interesting-dull, and exciting-boring. Anxiety has tense-relaxed, work-play, scary-fun, insecure-secure, and disgusting-attractive. The adjective pairs for Intellectual Accessibility factor are complicated-simple, confusing-clear, easy-hard, challenging-unchallenging, and comprehensive-incomprehensible. In ASCI survey, one item is specifically distinct, and this is the Fear item: safe-dangerous. Adjective pairs for Emotional Satisfaction item are pleasant-unpleasant, comfortable-uncomfortable, chaotic-organized, and satisfying-frustrating[37]. Data collection and analysis of the ASCI survey and its results are discussed in separate chapters focused on the piloting, implementation, and integration of the CRCE modules.

4.6.3. Colorado Learning Attitudes about Science (CLASS-Chem) Survey

The extensive development of CRCE modules required the need to evaluate its impact on students' beliefs about chemistry and the learning of chemistry. The belief here represents student personal knowledge of understanding that are related to their attitudes and subject norms[38]. Colorado Learning Attitudes about Science (CLASS-Chem) (**Appendix 15)**.

CLASS-Chem is a modified version of CLASS survey initially designed to measure various facets of students' attitude and beliefs about learning physics[15]. The only difference is that, in CLASS-Chem, 11 new chemistry-specific statements which involved reactivity, visualization, and molecular structure were added by the researchers. The CLASS-Chem 50 items survey measures student personal interest, real world connection, problem solving sophistication, sense making/effort, conceptual connection, conceptual learning categories, problem solving general, problem solving confidence, and atomic-molecule perspective of chemistry.

Statements in CLASS-chem survey are designed to address a wide variety of student beliefs about 1) learning chemistry, 2) structure of chemistry knowledge, 3) the content of chemistry knowledge, and 4) the connection of chemistry to the real world[38]. In Class-Chem survey, students "overall percent favorable" score is the percentage of responses for which the student agrees with an expert (same answer that a chemist would have provided to the question). Similarly, the "overall percent unfavorable" score is the percentage of responses for which the student disagrees with the expert response (novice-like response)[38]. The survey is designed for use with a broad population and takes about 15 minutes to complete. This survey several aspects that contribute to the students' attitude and beliefs about chemistry.

In CLASS-Chem, students are asked to respond on a Likert-like (5-point agree to disagree) scale to survey items. More on survey validation are explained in depth in papers of Adam et al[15, 38]. Also, the process of selecting the categories of questions and determining their robustness can be found in the same work. The CLASS-Chem was administered before (pre) and after (post) to students during the three stages of piloting, implementation, and integration of the CRCE modules in the general chemistry survey course.

CLASS-chem 50 items focus on the student thinking and beliefs towards the chemistry concepts. Monitoring students' beliefs provided the information about how the modules influenced student views about chemistry and what it meant for students participating in the CRCE modules to learn chemistry. All items in the survey are scored for the overall assessment of student beliefs, and corresponding items are scored for each of the categories listed above. Each category consists of questions that correlate with one another and target student thinking about chemistry. With the help of the survey, CRCE study has generated some very interesting results which are discussed in following chapters. The study looked at changes in students' attitudes over 3 semesters and to determine the impact of the CRCE modules on the attitudes and beliefs of students regarding the subject of chemistry.

4.7. Development of Culturally Relevant Education (CRE) Survey

For systematically studying the impact of modules, it was important to understand how the modules were contributing to student understanding of chemistry and student perception of modules based on their own experience with the CRCE modules. Since there was no survey instrument that addressed this issue of understanding such curriculum modules that relate to a specific and general cultural references and the connection of such ideas to the concepts in general chemistry, a survey was developed to address this need.

A survey focused on CRCE modules for students in the general chemistry survey course was developed. The survey has 16 items on various aspects of the modules and student experience based on 5-point Likert scale (1-strongly disagree, 2- disagree, 3- neutral, 4-agree, and 5- strongly agree) was developed and administered at the end of 2 semesters (**Appendix 16**).

To address the appropriateness and validity of the items in the CRCE survey, the survey was reviewed by a chemistry education faculty, a graduate student (majoring in chemistry), and an undergraduate student (majoring in biology education). Each reviewer independently viewed the survey items related to the CRCE modules and all the reviewers concurred that the items were concise, clear, and easily understood.

In the CRCE survey, students were asked to express how studying chemistry help them gain knowledge that will be useful in their lives outside college. The items also probe student views of the study of chemistry and its impact, their views of how the world works, and whether knowledge in chemistry is made up of several related topics that build on each other. The survey also included items on the relationship between indigenous or traditional practices and modern scientific approaches representing, and that if chemistry is applicable to everyday life and students own cultural background.

Prior to collecting any data from students, the Human Subjects Research- The Collaborative Institutional Training Initiative (CITI) program trainings were completed by the project supervisor and the graduate researcher. The study approval certificate was also obtained that included approval of the research purpose, methods and the various informational and assessment tools used for this project. The survey instruments, interview protocol, and standardized tests were approved by the South Dakota State University's

Institutional review board (IRB). The next chapters focus on the various stages of piloting, implementation and integration, the data collection, and findings from each stage of CRCE in the first semester general chemistry survey course.

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CHAPTER FIVE

PILOTING OF CRCE MODULES: KNOWING WHAT WORKS AND WHAT TO DO NEXT

5.1. Introduction

In 2016 Aronson and Laughter conducted a review of studies on culturally relevant education in the disciplines of science, mathematics, social sciences, language arts, and English as a second language for the term culturally relevant education[1]. Social-oriented pedagogies that include culturally inclusive effective teaching practices for diverse students constitute a Culturally Relevant Education (CRE)[2-5]. According to Aronson and Laughter using constructivist methods to develop bridges connecting students' cultural references with their academic skills is indisputably important[1].

This chapter describes the piloting of the CRCE modules in an online D2L based chemistry survey course. CRE researchers emphasize that, the student's cultural practices are assets rather than stumbling blocks to their learning process[1, 6-16]. Therefore, modules provided examples that are relevant to the lives of the students and included cultural references to the practices of Native Americans.

5.2. Piloting of CRCE Modules

A pilot study of draft CRCE modules was a critical stage in the CRCE research project. Piloting of CRCE modules was conducted to identify potential problem areas in the modules prior to implementation and integration in the general chemistry course. Piloting stage of CRCE study provided the conceptual premises from which the assumptions of the implementation of modules were drawn; modules developed during the piloting stage assisted in developing additional modules on all the topics considered for the scope of this study.

CRE framework also guided in determining the cultural elements and practices to be included in the modules. Two modules on the matter and measurement and chemical reactions concepts were used for pilot study. Piloting study involved the use of research protocols that involved data collection instruments, sample recruitment strategies, and other study techniques for the preparation of implementation and integration stages. Piloting of CRCE modules provided the groundwork in CRCE study and focused on determining the impact of developed modules on students’ academic performance, conceptual understanding, motivation and self-regulation, and attitudes in the subject chemistry.

5.2.1. Research Questions: Piloting of CRCE Modules

The research questions addressed during piloting of CRCE modules were (a) what is the impact of developed CRCE modules on student academic performance? (b) Do the CRCE modules impact student conceptual understanding and their awareness of chemistry and culture? and (c) Do the CRCE modules impact (a) student motivation and self-regulation, and (b) student attitudes towards the subject chemistry?

5.2.2. Methods for Piloting of CRCE

5.2.2.1. Piloting Study Setting and Participants

The institution for piloting CRCE study was a large Midwestern research university. Pilot stage of CRCE study was conducted in the Summer of 2019.
During summer term, the general chemistry course is offered online via the D2L Learning Management System. About 42 students were enrolled in the course. This small sample is typical of students who take the summer online general chemistry course. Out of the 42 students who were enrolled in the course, 35 consented to participate. 23 (65.63%) of the sample were females and 12(34.38%) were males.

5.2.2.2. Data Collection

The first and last week of the class were assigned for pre and post assessments: CLASS-Chem and SALES surveys and MOSART and CAST standard tests. MOSART and CAST standard tests were used to assess any shift in students' academic performance. All instruments have already been validated [17-21]. Data was also collected for student discussions related to modules. Students responses to discussion prompts on D2L discussions were analyzed to determine the impact of CRCE modules on students conceptual understanding. Prompts used for students to discuss on modules can be found in **Appendix 11.** The CLASS-chem survey was used to measure specific attitude categories by looking at subsets of statements probing students' attitudes in chemistry after their experience with the CRCE modules. SALES survey was used to measure the outstanding factors relating to the motivation and self-regulation of the students enrolled using the modules in the piloting stage of CRCE.

5.2.2.3. Data Analysis

5.2.2.3.1. Assessment of Student Academic Performance

Assessment of student academic performance was conducted using student scores in both pre- and post-CAST and MOSART tests. Out of the 35 students who participated, 19 students completed both pre and post CAST and MOSART assessments for which the mean, and standard deviation were calculated. During significance testing, statistical significance was set at 0.05 and p values were reported for both tests. Further analyses were done to test the effect size of CRCE modules on academic performance.

5.2.2.3.2. Assessment of Student Conceptual Understanding

Students posts during discussion on both modules were copied into one document and openly-coded using ATLAS-ti software. About 29 students participated during the module discussions. The coding of students posts followed an inductive approach. At the beginning of coding, every individual post was read multiple times before the coding process. Initial round of open codes focused on student post on the topics and the explanation associated with each topic. Each student post with explanation of concepts and the example provided by students was analyzed for correctness and its connection to the content presented via the materials.

Another round of coding further grouped down the codes that correponded to overall 6 codes that directly corresponded to the discussion prompts for both modules: Conceptual Understanding, Conceptual mismatch or gap, Incorrect understanding/poor conceptual knowledge, and relevance of chemistry (subcategories under relevance of chemsitry were personal application, professional application, and impact on life). The following are the definitions of each code.

1. **Conceptual understanding (CU)** includes – scientifically correct explanation and definition of concept in detail along with examples that are coherent and consistent.
2. **Conceptual mismatch or gap (CM-G)** means that students are not able to correctly tie the concept or explain it in words and they mismatch the example with the concept, or their explanation lacks details along with example. There is an apparent inconsistency in student response as compared to the scientifically correct conceptual explanation. Some coherence in statement of concept and example.
3. **Incorrect understanding/poor conceptual knowledge (I-CU)** means there is essentially a complete lack of understanding in response in discussion and student is not showing any coherence between statement of concept and example.
4. **Relevance of chemistry/ concepts** means to student as evidence in either in context of:

a) **Personal application (R-PER):** Student provides examples in response to discussion prompts that are more personal in nature for example – brushing teeth or walking to class or things done in and around home.

b) **Professional application (R-PRO)**: student provides examples in response to discussion prompts that are more professional oriented for example job, career, or work settings.

c) **Impact on life (I-OL):** Student sees big picture and provides examples in discussion in terms of how the chemistry impacts environment, life, human body, sustainability, industry, a certain field etc.

Code frequencies were determined from the ATLAS.ti program to see the code recurrence during the coding of students' discussion posts. A color coding scheme was used to generate a frequency of these codes as presented in results.

5.2.2.3.3. Assessment of Student Attitude Using CLASS-Chem Survey

CLASS-chem was used to study student attitudes during piloting of CRCE modules. The CLASS-Chem is described in detail in chapter 4 and also available in Appendix 9. For CLASS-Chem survey, 9 respondents completed the pre and post items. These responses were organized and analyzed using the CLASS-Chem analysis designed template for CLASS-Chem data analysis[19, 22]. Individual responses were averaged to determine the "overall percentage favorable" for all participants. The "overall favorable percentage" score was measured in terms of statements to which the students answered in the favorable senses, agreeing with an expert response.

5.2.2.3.4. Assessment of Student Motivation and Self-Regulation Using SALES Survey

SALES survey was used to measure student motivation and self-regulation during piloting of CRCE modules. SALES survey is described in detail in chapter 4 and also available in Appendix 13. Categories mean and standard deviation values were calculated and the mean scores for each of the four SALES categories were compared using paired sample t-test. SALES survey data were also analyzed quantitatively by calculating the cumulative score for each category. As explained in previous chapter the items in SALES instrument are grouped under 4 categories. These categories are Learning Goal Orientation (LGO), Task Value, Self-efficacy, and Self-regulation. Each category has 8 items. SALES items are 5-point Likert scale, with the scores ranging from 1= strongly disagree to 5 = strongly agree.

At the piloting stage, only 10 students completed both the pre and the post SALES survey. The cumulative score for individual category was then expressed in three scales.

32 -40- High Motivation and Self-regulation

25-31 - Acceptable Motivation and Self-regulation

≤ 24 - Requires improvement on Motivation and Self-regulation

5.2.3. Results and Discussions

5.2.3.1. Academic Performance Analysis

Student academic performance was based on student scores in MOSART and CAST pre and post CRCE. These two standard tests are described in detail in chapter 4. Student scores were transferred to an excel spreadsheet for analysis. Scores were calculated as percent values. A change in student mean ± standard deviation from pre to post were calculated (**Figure 5.1**). Pre and Post MOSART mean ± standard deviation was 57±3 and 60±4, respectively. For CAST standard test, these changes for pre and post CRCE were 67±5 and 69±6, respectively. During significance testing, statistical significance was set at

0.05 and p values above that were reported for both tests (**Table 5.1**). There was no significant difference between pre and post MOSART (*p value* = 0.53). The same was seen for CAST with *p value* of 0.65. Effect size calculation using Cohen's d indicated small effect sizes of 0.20 and 0.08 between pre and post MOSART and CAST tests. Focusing specifically on normality, a Shapiro-wilk test was performed showing no skewness, suggesting normal distribution (**Table 5.1**). Tukey Fence test also supplied no potential outliers in both tests. Analysis on both standard tests show an increase in students average scores though the performance was not statistically significant as evident from the analysis of pre and post mean score.

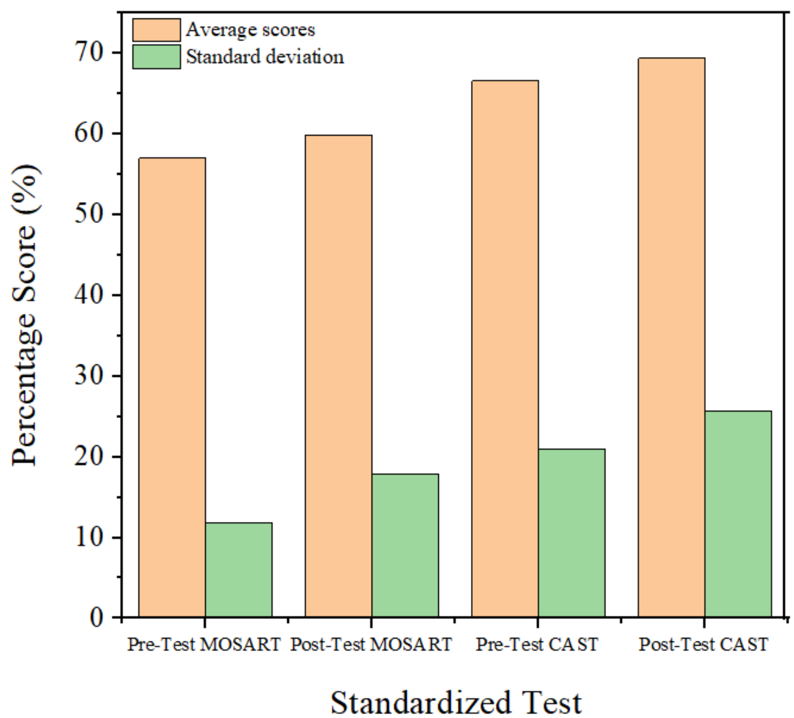

Figure 5.1. Descriptive analysis (CRCE on students' academic performance)

Table 5.1 Analysis of CRCE impact on students' academic performance

Inferential Analyses	**Pre vs Post test (MOSART)**	**Pre vs Post test (CAST)**
P value (α =0.05)	0.53	0.65
Cohen's D (Effect size)	0.20	0.08
Normality (α=0.05) Shapiro Wilk test	0.73	0.92
Outlier (Tukey Fence Test)	No potential Outlier	No potential Outlier

p value was calculated using a two-tailed student's t-test between pre and post results.

5.2.3.2. Results and Discussion of students' Discussion posts for the CRCE Modules on Conceptual Understanding

From the students' discussion posts analysis as described above, the frequency of the code related to the scientifically correct explanation of matter and measurements was 153 (**Table 5.2**).

Table 5.2. Frequency of Codes and Summary Data (Matter and Measurement)

Code	Color Coding Scheme	Code Frequency-Matter and Measurement	Total Code Score
CU	Green	153	306
CM-G	Orange	51	51
IC-U	Red	0	0
R-PER	Brown	143	143
R-PRO	Blue	27	27
I-OL	Yellow	40	40

An example of conceptual understanding would be;

Measurements that I use in my everyday life include baking and cooking measurements such as teaspoons, cups, and tablespoons. I also measure my gas when filling up my truck in units of gallons and measure the distance I travel in units of miles. When going to the doctor, my height and weight are measured in feet and inches, and pounds or kilograms. Measurements are used in almost every aspect of our lives.

Density is the mass of an object divided by its volume. I use density when filling balloons with helium because helium is less dense than air which causes the balloons to float. I also use density when filling a cup with ice and water because ice is less dense than water and floats on top, and I do not want to overflow the cup.

Likewise, and example of conceptual mismatch or gap based on student post is;

I believe that the scientific method does not need to be used in sequential order depending on your need. Some situations may require more experimentation while others require none. If the desired result is not found, one may need to return to the hypothesis and experimentation stages to produce a different result. The 3 states of matter all are evident in our surrounds. Solids have atoms that are packed close together and cannot move freely such as ice, rocks, and cell phones. Liquids have atoms that are relatively close together but are free to move a little and flow such as water, oil, and the gas we use in our vehicles. Gases have atoms very far apart that are free to move around and change shape and volume such as air, water vapor/steam, and carbon dioxide emissions.

If a student post met the criteria for conceptual understanding it was given a score of 2, and for the conceptual mismatch or gap the student post was scored as 1. The lowest score assigned for incorrect understanding or poor conceptual understanding was 0.

Most students were able to connect core chemistry ideas in matter and measurements to their everyday applications and to their cultural background. About 51 student responses were coded as conceptual gap/mismatch in response to the discussion prompts for module 1 on matter and measurement and scientific method module. It was found that along with explaining the terminologies, students were also applying concepts of measurements and scientific methods in their everyday and traditional activities. The number of times students referred to their personal application of the concepts of matter and measurement was 143. It is important to note that the discussion prompts were mainly guidelines and that the students were not required to respond to every prompt. Students also discussed the relevance of the concept of the matter and measurement in their work. Overall, 27 students' discussion posts included references to how they apply the ideas presented in these CRCE modules in their work settings. **Table 5.3** presents summary data, and examples of quotes from module 1 during the piloting of CRCE modules.

Module 2 during the piloting stage was focused on the concept of chemical reaction, and equilibrium. Analysis of student discussion posts in response to the discussion prompts to this module showed that students were able to conceptually explain enthalpy, entropy, spontaneous and non-spontaneous reactions. From the student discussion post analysis, the frequency of the code related to the scientifically correct explanation of chemical reactions was 194 (**Table 5.4**).

Table 5.3. Codes and representative quotations for student discussion on Module 1

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	I believe that the scientific method does not need to be used in sequential order depending on your need. Some situations may require more experimentation while others require none. If the desired result is not found, one may need to return to the hypothesis and experimentation stages to produce a different result. The 3 states of matter all are evident in our surrounds. Solids have atoms that are packed close together and cannot move freely such as ice, rocks, and cell phones. Liquids have atoms that are relatively close together but are free to move a little and flow such as water, oil, and the gas we use in our vehicles. Gases have atoms very far apart that are free to move around and change shape and volume such as air, water vapor/steam, and carbon dioxide emissions.	Measurements that I use in my everyday life include baking and cooking measurements such as teaspoons, cups, and tablespoons. I also measure my gas when filling up my truck in units of galloons and measure the distance I travel in units of miles. When going to the doctor, my height and weight are measured in feet and inches, and pounds or kilograms. Measurements are used in almost every aspect of our lives. Density is the mass of an object divided by its volume. I use density when filling balloons with helium because helium is less dense than air which causes the balloons to float. I also use density when filling a cup with ice and water because ice is less dense than water and floats on top, and I do not want to overflow the cup.
Conceptual mismatch or gap (CM-G)	My great-grandfather utilized the scientific method when he made the decision to move from Central-Oklahoma to North-eastern Wyoming. He faced a bleak financial future in Oklahoma, so he pondered if moving to Wyoming would be more promising, than staying in Oklahoma. So, he moved to North-eastern Wyoming and homesteaded, this venture proved	In a scientific application, it is a standard to follow the scientific method to the letter, but in a more “at-home” application, I believe that the scientific method is more flexible, we still use all the steps but change the order up a little. The steps of the scientific method are always used in sequential order. Using the example form above, going on a diet uses the steps in order. A person sees an

	to be successful because he lived the rest of his life in Wyoming.	ad on social media, or in an ad on television or on a poster at a gym. This is the person's observation. usually the ad comes with a picture of a person with the body they want to have. More than likely, for a hypothesis for a diet would be that if they stick to it, they will lose so many pounds promised by the ad. The "performing an experiment" part is doing the actual diet. The conclusion would be if the diet worked as promised or if it did not. The results or findings for a diet would be the number of pounds lost in how much time. Some people even take before and after pictures to show the physical difference seen. The reporting of the results could be as small as telling your friends about if it worked, to posting the before and after pictures on social media explaining how you felt about the diet.
Incorrect understanding/poor conceptual knowledge (I-CU)	NA	NA
Relevance of chemistry/ concepts to student as evidence in either in context of		

a) Personal application (R-PER)	Living in the Midwest, we easily come across all states of matter in our surroundings. When the lakes freeze, it forms a solid because of the ice. When the lakes melt, it becomes a liquid because it is back to the water consistency. When it is humid outside, it is the water vapor in the air making it into a gas.	The simplest scientific method I use every day would be at home before I go outside to figure out what type of clothes go with how the weather is outside. I'd use observation to see if it's sunny, rainy, etc. Forming a hypothesis such as wearing pants or shorts just because the sun is shining does not mean that it's going to be hot outside. Then, I'd perform the "experiment" by stepping outside to see how it feels to be in what I decided to wear that day. Drawing the conclusion would be if the outfit is right for the weather.
Professional application (R-PRO)	I use the scientific method when raising my animals for the county fair. Every year, I look for the best feed to improve my goats. I make observations on the animal’s condition and body type. Some goats come with more baby fat and need more protein and less fat. While others could use a covering to their muscle. Try the new feed changing only one thing at a time when looking to see if it has improved the goats covering and condition.	
Impact on life (I-OL)	This module has helped me realize how the Native Americans shaped our use of the scientific method and how they are responsible for many of our practices today such as measurements and medications. The Native Americans first began measuring with their hands, feet, fingers, and toes which evolved	I thought the module was a great way to integrate Native sciences into contemporary science since there are other forms of science that may be overlooked and not thought of as a science discipline. The Native American Sciences was a great example of how science is like second nature to us

	into the measurements we use today. They also found that aloe vera had a cooling effect and could be used to heal sunburns which we still use today. Although they did not know all the reasons for the effects of some medications, they were able to use trial and error and observations to find uses for the medications we have today.	and that it is not done by people working in a laboratory with white jackets on. From reading others' posts, it seems that everyone understands the concept of scientific methods and how it impacts us every day and that we do not realize that we are doing scientific method!

Table 5.4. Frequency of Codes and Summary Data (Chemical Reaction)

Code	**Color Coding Scheme**	**Code Frequency-Chemical Reaction**	**Total Code Score**
CU	Green	194	388
CM-G	Orange	23	23
IC-U	Red	8	0
R-PER	Brown	36	36
R-PRO	Blue	1	1
I-OL	Yellow	43	43

Examples of conceptual understanding would be;

Exothermic Reaction- Is a chemical reaction that releases energy into its surroundings. Reactants -> Products +Energy. An example would be starting a fire. energy plus oxygen and wood for continued fuel produce carbon dioxide, heat, and water. Endothermic Reaction- Is a chemical reaction that absorbs energy from its surroundings. Reactants +Energy -> Products. An example is photosynthesis CO2 plus H20 produce sugars and oxygen in the presence of sunlight.

Combination Reaction - 2 or more reactants combine to form a single product- Decomposition Reaction - 1 compound reactant breaks down into 2 or more simpler products - Single Replacement Reaction - 1 element replaces another element in a compound - Double Replacement Reaction - 1 element from each compound replace each other (swap partners) - Precipitation Reaction - 2 or more reactants produce an insoluble solid in solution - Neutralization Reaction - an acid and a base react to form water and a salt - Redox Reaction - involves the transfer of electrons when the oxidation number of one substance changes due to the loss or gain of electrons.

The frequency of the code related to incorrect conceptual explanation or in words and they mismatch the example with the concept was 23. Also, 8 of the students' discussion posts were coded incorrect due to poor application of conceptual knowledge. Example of conceptual mismatch or gap based on student post is;

Neutralization Chemical Reactions -When an acid and base react together and form water.

Precipitation Reaction-When there is a reaction that causes a solid to be byproduct.

Students showed transfer of ideas from entropy, and spontaneous reaction into the real-world scenarios. In addition to discussing the types of chemical reactions, students also shared the connection of these ideas, and the impact of various reactions on their lives. Overall, there were 43 instances in students' discussions wherein students discussed the relevance of chemical reactions in terms of big picture of viewing reactions as highly applicable to the discipline of life in general.

Also, students were able to relate their understanding of chemical reaction to their personal applications. There were 36 instances in students' discussions wherein students brought up personal applications. For professional application, only one student discussed how learning the concept of chemical help the work environment. **Table 5.5** presents summary data, and examples of quotes from students' discussions on chemical reactions during the pilot stage of CRCE.

Table 5.5. Codes and representative quotations from student discussion posts – CRCE module - Chemical Reactions

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	According to our module, entropy is a measure of the amount of molecular disorder in a system. An example would be popping popcorn. Our book also states that Enthalpy is a measure of the amount of energy associated with substances involved in a reaction. An example would be boiling water.	Exothermic Reaction- Is a chemical reaction that releases energy into its surroundings. Reactants -> Products +Energy. An example would be starting a fire. energy plus oxygen and wood for continued fuel produce carbon dioxide, heat, and water. Endothermic Reaction- Is a chemical reaction that absorbs energy from its surroundings. Reactants +Energy -> Products. An example is photosynthesis CO2 plus H20 produce sugars and oxygen in the presence of sunlight.
Conceptual mismatch or gap (CM-G)	Combustion Reactions- Produce heat when oxygen and carbon containing substance combine.	Precipitation Reaction-When there is a reaction that causes a solid to be byproduct.
Incorrect understanding/poor conceptual knowledge (I-CU)	Precipitation reaction is the product of two aqueous solutions.	Combustion Reaction: This reaction produces heat when oxygen and carbon combine.
Relevance of chemistry/ concepts to student as evidence in		

either in context of		
Personal application (R-PER)	My family uses energy when we burn wood in the wood burning stove to keep the house farm. I use chemical reaction and energy rates to cook and bake. I would use chemical equilibrium for when I use the mini toaster oven to bake small pizza and small dishes that I do not want to use the oven for.	My family has used chemical reactions when farming. My dad has to mix chemical in order to kill weeds in our fields. It may take a couple days to see results, but when the weeds die, we see that our mixture of chemicals was a success. We use energy every day in our house by turning on the lights. Finally, we use rates and chemical equilibrium by cooking as we must wait for heat and products to finish cooking.
Professional application (R-PRO)	Module has helped me understand why things were solved for our uses today. I have learned a lot in the class that have helped me with my job even. I work in a hospital and surprisingly somethings I have learned have helped me better myself in my work environment. I really enjoy chemistry because it makes me think a different way than everyday use.	NA
Impact on life (IOL)	There are so many needs that these processes fulfill, that it is hard to begin! I think of the medical discussion of chemical imbalance and how those are balanced using different diagnostics and medication available today. I also think about energy and how it cannot be created or destroyed, and where does it go.	Chemical reactions, energy rates and equilibrium are all extremely important for human needs. Not just currently but throughout history we have needed these processes to survive. These processes keep us healthy, hydrated, and nourished. Without them we would literally be dead

Analyzing students' discussions posts and coding of students posts show that students learned and understood the key ideas presented in the modules on matter and measurement and chemical reactions. In their discussions, students did not merely define the terms but rather they expanded their situational knowledge from the course materials and modules introduced in the online class into their real world. These analyses on students' discussion posts showed a deeper conceptual understanding on the matter and measurement as well as chemical reactions concepts as depicted in code frequencies and code examples that show specific student quotations.

5.2.3.3. Impact of CRCE modules on Student Attitudes

CLASS measures student attitudes and beliefs in chemistry. Details of CLASS-chem are provided in chapter 3. There was an increase in favorable percentage scores for Problem solving general (PS: General), problem solving confidence (PS: Confidence), and Atomic-molecule perspective of chemistry categories from 52.8 to 57.7 (Shift of 4.8%), 58.3 to 72.2 (large shift of 13.9), and 51.9 to 66.7(large shift of 14.8) respectively at the piloting stage. These results from the pilot stage show that CRCE modules contributed to an improvement in student general problem solving and confidence, as well student perspective on atomic molecular concepts in chemistry though quantitatively, a negative shift was observed in their personal interest, real world connection, problem solving sophistication, sense making/effort, conceptual connection, and conceptual learning categories. The CLASS-Chem also showed a negative shift in the overall student attitudes during the piloting stage (difference in shift was -0.8%). Students "overall favorable percentage" scores for pre and post were 51.5 and 50.7. Regression in attitude and unsuccessful shifting attitude to be more expert-like were observed for personal interest, real world connection, problem solving sophistication (PS: sophistication), sense making/effort, conceptual connection, and conceptual learning categories from the pre to the post with respect to individual favorable percentage scores and differences in average shifts.

Table 5.6. Comparison of summer general chemistry students' favorable responses for pre and post survey on students' attitude in chemistry.

Survey Response Categories	Favorable Pre-survey Response (%)	Favorable Post-survey Response (%)	Difference in Average Shift (%)	Standard Error in Shift (%)
Overall	51.5	50.7	-0.8	2.7
Personal interest	61.1	51.9	-9.3	7.5
Real world connection	75.0	48.1	-26.9	9.5
PS: general	52.8	57.7	4.8	5.3
PS: confidence	58.3	72.2	13.9	6.9
PS: sophistication	36.5	33.3	-3.2	6.7
Sense making/effort	67.7	64.2	-3.5	6.0
Conceptual connections	52.4	40.2	-12.2	8.2
Conceptual learning	25.4	22.2	-3.2	7.0
Atomic-molecular perspective of chemistry	51.9	66.7	14.8	10.3

Note: N=9

5.2.3.4. Impact of CRCE on student Motivation and Self-Regulation in Pilot Stage

Results in this section is based on the analysis of the SALES survey data as described in the data analysis section. The SALES survey measures four constructs that related to student motivation and self-regulation (**see Appendix 13**). SALES is a 5-point Likert scale-based survey with the scores ranging from 1= strongly disagree to 5 = strongly agree. The survey has 32 statements, and 8 statements correspond to each of the four factors (categories) that relate to student motivation and self-regulation.

The four categories for student adaptive learning and engagement in science include:

1. Learning Goal Orientation (LGO)
2. Task Value (TV)
3. Self-Efficacy and (SE)
4. Self-Regulation (SR)

Also as described before in data analysis section for SALES survey at the piloting stage, only 10 students completed both the pre and the post SALES survey. Impact of CRCE modules on student's motivation and self-regulation was evaluated based on the mean and standard deviation values for each category. The pre mean value for LGO TV, and SR were 4.31, 3.90, and 4.28, respectively. At the end of the semester, the mean values increased (LGO, TV, and SR were 4.38, 4.15, and 4.36 respectively) showing a positive shift in LGO, TV, and SR except for SE category. The pre-post mean values for SE decreased from 4.05 to 4.00. Further analysis on mean scores for each of the SALES categories set at 0.05 showed no significant difference between the pre and post for all the four categories (**Table 5.7**).

Table 5.7. Summary of pre- and post-SALE survey on student's motivation and engagement.

SALE Survey (Category)	**Pre-SALE Response**		**Post-SALE Response**		**Paired-t-test value**	**p-value**
	Mean	S.D.	Mean	S.D.		
LGO	4.31	0.48	4.38	0.37	0.51	0.62
TV	3.90	0.43	4.15	0.34	2.05	0.07
SE	4.05	0.45	4.00	0.55	-0.13	0.70
SR	4.28	0.36	4.36	0.28	-0.63	0.55

SALE survey data were also probed for clarity and future planning of study after piloting. Data was analyzed quantitatively by calculating the cumulative score for each category**.** There was a positive shift in number of students who had high Learning Goal Orientation from the pre to the post. At the beginning of the semester, 8 (80%) students had high Learning Goal Orientation, but this number increased to 10 (100%) at the end of the semester (**Figure 5.2**).

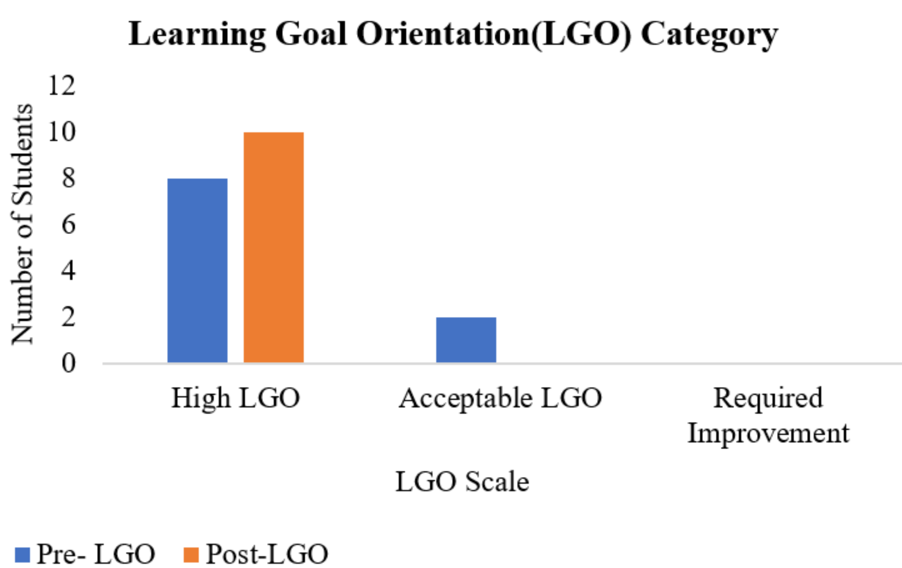

Figure 5.2. Impact of CRCE on students Learning Goal Orientation (LGO).

The number of students who had higher task value increased from 50% to 70% from the pre to the post (**Figure 5.3**). This depicted student's appreciation in performing the assigned task.

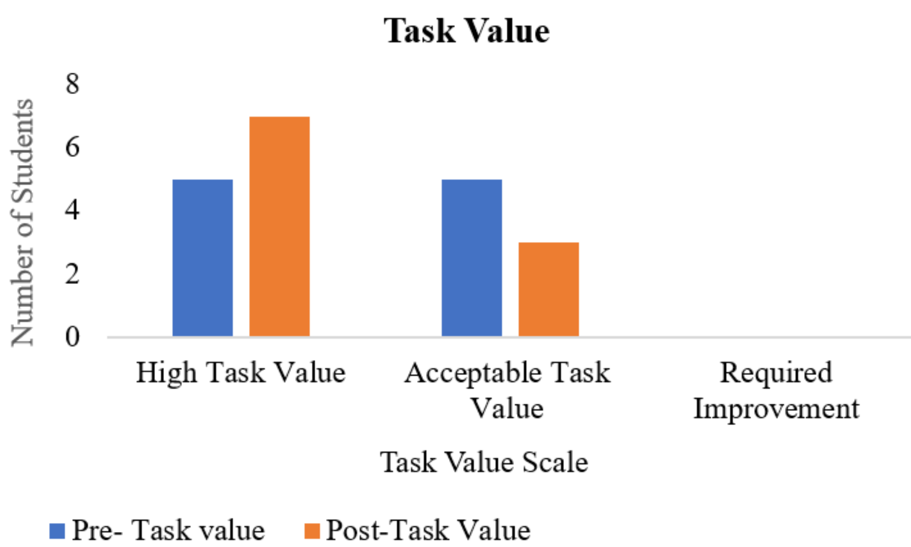

Figure 5.3. Impact of CRCE on students Task Value.

For Self-Efficacy category, there was shift from high scale to acceptable scale. The percentage of students who had high self-efficacy reduced from 70% to 60% from the pre to the post (**Figure 5.4**).

Figure 5.4. Impact of CRCE on students Self-Efficacy

Self-Regulation category also showed an increase in number of students with high self-regulation. The number of students with high self-regulation increased (10%) from the pre to the post as displayed in **Figure 5.5**.

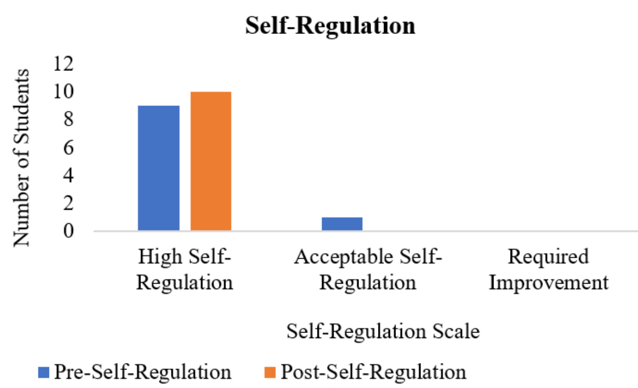

Figure 5.5. Impact of CRCE on students Self-Regulation.

Systematically, these analyses confirm to the positive shifts in students' Learning Goal Orientation, Task Value, and Self-Regulation achieved through calculation of their mean scores though further analysis on mean scores using paired sample t-test showed no statistical difference between the mean scores.

5.2.4. Conclusion of Piloting Stage

Results from piloting of CRCE modules show the impact of CRCE on improving students' academic performance. Though the performance was not statistically significant between pre- and post-CAST and MOSART scores as evident from the analysis of pre and post mean score, there is an increment in student mean scores from the pre to the post.

The conceptual understanding was evaluated via students' discussion posts. Based on discussion code frequencies and student scores for the codes related to conceptual understanding and conceptual mismatch/gap, there is a greater number (CU= 153 for matter and measurements, and CU= 194 for chemical reaction) of students showing conceptual understanding as compared to students showing conceptual mismatch for each module during the piloting stage (CM-G= 51 for matter and measurement, and CM-G= 23 for chemical reaction). Similarly, it was found that along with explaining the terminologies, students were also applying concepts in their everyday and traditional activities. The number of times students referred to their personal application of the concepts of the matter and measurement and chemical reactions were 143 and 36, respectively. It is important to note that the discussion prompts were mainly guidelines and that the students were not required to respond to every prompt.

Beliefs represent a person's "personal knowledge or understandings that are precursors and experiences that contribute to the attitudes and subjective norms". Characterization of student's attitudes and shift in these categories over the course was observed in CRCE intervention when assessed via the CLASS-Chem survey. CRCE was highly successful at achieving the goal of improving students' general problem solving and confidence (average shift of 4.8% and 13.9% respectively), as well their perspective on atomic molecular perspectives in chemistry (difference in average shift =14.8%) though a negative shift was observed in their personal interest, real world connection, problem solving sophistication, sense making/effort, conceptual connection, and conceptual learning categories during the piloting stage.

The CRCE modules were aimed at improving student academic performance, student conceptual understanding, and student motivation and self-regulation, and attitudes. The pilot stage has shown mixed results. There is an indication of improvement in student academic performance even if it remains statistically insignificant. Student conceptual understanding also appears to be promising, considering that students used examples from modules and tied the concepts to their personal and professional aspects of life including their background and ancestry. This is helpful to develop next set of modules and to revise the modules that were used during the pilot stage.

The results for student motivation and self-regulation also showed some positive aspects of the impact of modules on Learning Goal Orientation (20% increase in number of students with high LGO from pre to post), Task Value (20% increase in number of students with high Task value from pre to post), and Self-Regulation (10% increase in number of students with high Self-Regulation from pre to post for assessing their motivation and self-regulation which are realistic in nature. Although these analyses are inconclusive at this early stage of piloting, the results are helpful for the module development work and to establish a framework for the next stages of the CRCE modules implementation and integration in a large enrollment face-to-face section of the general chemistry survey course.

5.2.5. Limitation and Future work after Piloting of CRCE Modules

The coverage of piloting of CRCE modules was limited to only students who took the summer online general chemistry class, resulting in small number of participants. Based on the positive outcomes in the piloting stage, three additional modules were developed as planned in the beginning of this project. Further plans were made to collect data for revised modules from piloting stage, and the three newly developed modules. The impact of CRCE modules during the implementation and integration stages is presented in subsequent chapters.

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CHAPTER SIX

IMPLEMENTATION OF CRCE: SMALL STEPS AND A GIANT LEAP TOWARDS DIVERSITY

6.1. Introduction of CRCE Implementation

The development of curriculum and educational resources that is supportive of diverse cultures is crucial considering rapid and sustained globalization[1]. Unfortunately, the educational system today is devoid of important practices and examples, making the system consumptive instead of being productive as students are taught to master the subject without relating them to their everyday activities outside the classroom[2]. Despite a keen interest to pursue science, students divert from science and the few that survive the rigors do not see a relationship between what they learn in science classrooms, what they learn from the curricular resources, and what they encounter daily[3].

To address the challenge of disconnected content that leads to lower student self-regulation and motivation in chemistry, the CRCE project focused on developing student-centered modules connecting every day and cultural practices to the chemistry content. The purpose of these modules was to engage students to critically reflect on the chemistry concepts and draw connections to the culture of a place and their own life in general. Overall, five modules were developed for this project (These modules have been described in detail in the prior chapter (**Chapter 3**). In the context of this study, all developed modules were implemented in the course. During the implementation stage, data was collected on students' academic performance, conceptual understanding, motivation and self-regulation, and attitudes. The purpose of CRCE implementation was to test effectiveness of modules on students' academic performance, conceptual understanding, attitudes, and motivation and self-regulation toward chemistry.

6.2. Research Questions on Implementation of CRCE Modules

CRCE implementation intended to explore importantly these questions:

1. What is the impact of the implementation of CRCE modules on student academic performance in a large enrollment general chemistry course?
2. Do implemented CRCE modules impact the conceptual understanding and cultural awareness of student in general chemistry?
3. Does the implementation of CRCE modules change student attitudes toward the subject chemistry? Are there any differences between students' attitudes towards the subject chemistry?
4. Does implementation of CRCE modules impact undergraduate students' motivation and self-regulation in the learning of chemistry?

6.3. Research Methods for Implementation of CRCE

6.3.1. Setting of CRCE Implementation

Study on implementation of CRCE was conducted in a public research Midwestern university in the United States of America. The institution is the same place the piloting study of CRCE took place. Fall 2019 semester was targeted for the implementation of CRCE modules in the general chemistry survey course. General Chemistry Survey (CHEM 106) is a three-credit lecture course with a one-credit laboratory course as a corequisite. The course is introductory in nature and covers the basic principles of chemistry. The course consists of three 50-min lectures per week which introduces a survey of basic chemical principles for students aspiring for careers in sciences (nursing, agriculture, exercise science or science or closely related fields).

General chemistry survey covers fundamental ideas about the states of matter and measurements made in chemistry, physical and chemical processes, the periodic table and element properties, ionic and molecular compounds, classification and balancing of reactions and stoichiometric calculations, rates and equilibrium, gases, liquids, solids, and solutions, acids and bases, and nuclear chemistry. These concepts help students appreciate the chemical compositions and changes that take place in the matter. The topics covered in this course are aimed at helping students apply their understanding of the scientific method to explore various problems in general chemistry.

6.3.2. Participants for CRCE Implementation Study

The participants of the study were students enrolled in one of the two large enrollment sections of the CHEM 106 survey course during the Fall 2019 semester. The lecture component of general chemistry survey course had 202 students. Among 202 students who were enrolled in the course, a total of 148 (46 males and 102 females) consented to participate, excluding students with a grade of incomplete. Students present in the course were diverse majors (nursing (N=82), construction management (N=4), operations management (N=1), precision agriculture (N=2), agricultural science (N=6), psychology (N=1), civil engineering (N=1), medical laboratory technician (N=2), wildlife and fisheries (N=10), dairy manufacturing (N=4), animal science (N=5), exercise science (N=6), ecology and environmental science (N=3), rangeland management and ecology (N=1), agronomy (N= 3), electrical engineering (N=2), natural resource law enforcement

(N=1), agric business (N=3), exploratory studies (N= 4), radiology (N=1), economic (N=2), and agricultural education (N=2). Two participants were indecisive on their majors.

Students' majors were further grouped under 5 categories: Health Sciences (N= 95), Agricultural Sciences (N= 40), Engineering (N=3), Social Sciences (N=3), and Other Majors (N=5). Majority of the participants (111) were Freshmen. The remaining were Sophomores (N=28), Juniors (N=6), and Seniors (N=3). The entire class population had 4 Native Americans, 3 Hispanics, 1 African American, 1 Caribbean, and 2 Asians. The rest of the participants were Caucasians (N=135).

6.4. Implementation of CRCE Modules

6.4.1. Data Collection

All 5 developed modules text files and videos were implemented in the general chemistry survey course during the fall 2019 semester**.** CRCE implementation and its effectiveness were based on the data collected in the form of pre-and post-standardized exams with the exception of ACS exams which was taken once at the end of the semester, 4 exams sets for the course, pre- and post-quizzes on modules, students' discussion posts on each module after its implementation, pre-and post-questionnaires and semi-structured qualitative interviews. The schematic for data collection during implementation stage of the CRCE modules is presented in **Figure 6.1**.

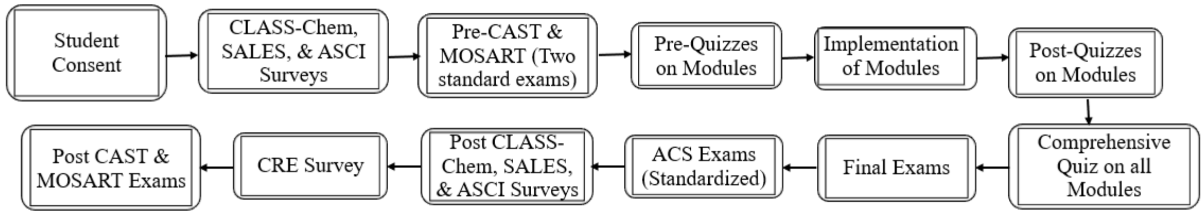


Figure 6.1. Chat showing how CRCE modules were implemented

The pre assessment tools were used at the beginning of the semester, followed by implementation of modules. Some assessment tools were implemented to gather data on student progress, and same were administered post-implementation of CRCE modules. Assessing the impact of CRCE implementation on academic performance was done through CAST, MOSART, ACS exams, 4 exams on chemistry chapters thought in the course, and quizzes on modules. To understand the impact of CRCE modules implementation on student conceptual understanding, data from student's discussion posts on each module after its implementation, were collected. Qualitative data on student conceptual understanding were collected from student online discussion posts. Attitude toward the Subject of Chemistry Inventory (ASCI) and Colorado Learning Attitudes about science survey (CLASS-Chem) were used for studying the impact of the implementation of CRCE on student attitudes.

Students' Adaptive Learning Engagement in Science (SALES) survey was used to measure the impact of implementation of CRCE modules on motivation and self-regulation of students. Means of administration of mentioned assessment tools was via a Learning System management (LMS) except the ASCI survey which was administered via a pencil and a paper format. Further explanations on these assessment tools can be found in **Chapter 4 and Appendix**. CRE survey was used to assess how the modules were contributing to student understanding of chemistry, and student perception of modules based on their own experience with the CRCE modules. CRE survey was only implemented at the end of the semester.

Based on student responses to D2L discussion prompts, students were invited for semi-structured qualitative interviews. Qualitative semi-structured interviews were conducted to assess student's ability to transfer and incorporate their newly acquired scientific knowledge from modules. Face to face interviews were conducted with 10 purposefully sampled students, and each interview took approximately 30 minutes. Selection of students for the semi-structured interview were students who read, watched, discussed, and answered at least 4 module files, videos, and questions through all modules.

6.4.2. Data Analysis

6.4.2.1. Assessment of Student Academic Performance

Data were transferred to excel file from the D2L. CAST, MOSART, ACS standard exams, all 4 exams, and quizzes on modules were analyzed using parametric and non-parametric approaches. Student academic performance was assessed using student scores in pre- and post-CAST, pre- and post-MOSART, pre- and post-Quizzes, and ACS exams for which the mean, and standard deviation were calculated. Also, difference in exam scores (exams 1-4 and ACS exam) between students who consented to participate, and students who did not participate were investigated. During significance testing, statistical significance was set at 0.05 and observed and corrected p values were reported for all tests. Further analyses were done to test the effect size of CRCE on academic performance. The percentage scores for all the 148 students who consented for participation were used for studying the impact of CRCE modules on academic performance.

6.4.2.2. Impact of Implementation of CRCE modules on Conceptual Understanding

Students' discussion posts on D2L were used to assess students conceptual uderstanding. Students posts were scored on a point scale based on the accuracy of student explanations and examples included in student discussion posts. The coding process followed similar protocols and procedures as described in **Chapter 5**. The coding scheme developed during the piloting stage was applied to the student discussion posts in the implementation stage to maintain consistency for coding and scoring the student posts. About 47 students answered D2L discussion prompts on all the five modules. The six codes were : Conceptual understanding, Conceptual mismatch or gap, Incorrect understanding/poor conceptual knowledge, and relevance of chemistry (subcategories under relevance of chemistry were personal application, professional application, and impact on life). The following are the definitions of each code.

5. **Conceptual understanding (CU)** includes scientifically correct explanation and definition of a concept in detail along with examples that are coherent and consistent.
6. **Conceptual mismatch or gap (CM-G)** means that students are not able to correctly tie the concept or explain it in words or they mismatch the example with the concept, or their explanation lacks details along with example. There is an apparent inconsistency in student response as compared to the scientifically correct conceptual explanation. Some coherence in statement of concept and example.

7. **Incorrect understanding/poor conceptual knowledge (I-CU)** means there is essentially a complete lack of understanding in response in discussion, and student is not showing any coherence between statement of concept and example.
8. **Relevance of chemistry/ concepts** to student as evidence in either or in context of:

a) Personal application (R-PER): Student provides examples in response to discussion prompts that are more personal in nature for example – brushing teeth or walking to class or things done in and around home.

b) **Professional application (R-PRO)**: student provides examples in response to discussion prompts that are more professional oriented for example job, career, or work settings.

c) Impact on life (I-OL): Student sees big picture and provides examples in discussion in terms of how the chemistry impacts environment, life, human body, sustainability, industry, a certain field etc.

Code frequencies were determined from the ATLAS.ti program to see the code recurrence during the coding of student discussion posts. A color coding scheme was used to generate frequency of codes as presented in results.

6.4.2.3. Assessment of CRCE Modules on Attitudes using ASCI and CLASS-Chem Surveys

Hard copies of students' responses to ASCI items were transcribed into an excel spreadsheet and analyzed using the scoring template designed by Bauer[4]. When entering students' responses in an excel spreadsheet, no items were left blank. In case where a student had provided same response for all items, the spurious data was not included in the analysis of ASCI. *The p value* and effect size between pre and post ASCI scales were calculated.

For the analysis of CLASS-Chem data, students responses for CLASS-Chem pre and post items were organized in an excel spreadsheet and analyzed as per the CLASS-Chem analysis template [5, 6]. Individual responses were averaged to determine the "overall percentage favorable" for all participants. The "overall favorable percentage" score was measured in terms of statements to which the students answered in the favorable senses, agreeing with the expert response.

6.4.2.4. CRCE Modules on Motivation and Self-regulation

Data from SALES Survey were analyzed quantitatively for the 4 categories: Learning Goal Orientation (LGO), Task Value (TV), Self-efficacy (SE), and Self-regulation (SR). Among the 148 students who consented to participate, a total of 35 responses were obtained from students who completed both the pre and post SALES surveys. Categories mean and standard deviation values were calculated and the mean scores for each of the four SALES categories were compared using paired sample t-test. The cumulative score for individual category was also calculated and expressed in three scales.

32 -40- High Motivation and Self-Regulation

25-31 - Acceptable Motivation and Self-Regulation

≤ 24 - Requires improvement on motivation and Self-Regulation

6.4.2.5. Investigating Students Experience with CRCE Modules

CRE Survey used to understand how the modules were contributing to student understanding of chemistry and student perception of modules based on their own experience with the CRCE modules. CRE survey data were analyzed by calculating the percentage of student's response to each scale (1-strongly disagree, 2- disagree, 3-neutral, 4-agree, and 5- strongly agree) for each item. A total of 42 responses were obtained from students who completed post CRE survey.

Also, data from students semi-structured qualitative interviews were collected and student response to each question was used to investigate student's ability to transfer and incorporate their newly acquired scientific knowledge from modules. 10 students' responses were obtained to assess each student ability to transfer and incorporate their newly acquired scientific knowledge from modules. Each interview took approximately 30 minutes.

6.5. CRCE Implementation Results and Discussion

6.5.1. Impact of Implementation of CRCE modules on Academic Performance

Student assessment is an important factor in every level of education. Outcomes from assessment serve diverse functions such as evaluation of student knowledge and the effectiveness of the educational intervention [7]. In this study, both pre- and post-quizzes that were conducted during implementation of modules were addressing student academic performance based on the students' mastery of content knowledge via modules, and in terms of students ability to answer questions relating to the concepts presented in the CRCE modules that were also covered in the lecture course. It was hypothesized that a student who took pre and post quizzes for the modules, read the text files, and watched the videos would perform well which will reflect in their mean scores on each of the assessments. The null hypothesis was that there will be no difference in student mean scores for each of the assessments.

Descriptive statistics (mean and standard deviations) and inferential statistics (effect size, and p-value) for exams and quiz scores were calculated. An increase in mean scores from pre to post was shown for all 5 quizzes. The pre and post of quiz 1 were 72.73±15.47 and 88.79±10.23. Also, large effect size between pre- and post-quiz depicts a larger effect between the pre and post mean scores on quizzes. From the results, large effect size was witnessed for quiz 1 (effect size=1.22), quiz 2 (effect size=0.71), quiz 3 (effect size=1.60), quiz 4 (effect size=0.95), and quiz 5 (effect size=1.49). For significance testing, statistical significance was set at 0.05 and p values less than 0.0001 were reported for all quizzes. All results on quizzes are presented in **Table 6.1**.

Table 6. 1. Analysis of student performance in Quizzes.

Statistical Analyses	**Quiz 1 (N=33)**		**Quiz 2 (N=66)**		**Quiz 3 (N=82)**		**Quiz 4 (N=90)**		**Quiz 5 (N=101)**	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Mean	72.73	88.79	79.85	88.33	48.17	78.90	77.56	94.00	71.68	94.56
S.D.	15.47	10.23	14.20	9.04	16.41	21.60	21.00	12.54	18.60	11.34
Effect Size	1.22		0.71		1.60		0.95		1.49	
t-Test	5.57		6.05		12.03		7.84		11.51	
df	32		65		81		89		100	
Observed p-value	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Corrected p-value	0.01									

For CAST and MOSART standardized tests, the changes for pre and post were 53.03±13.16 and 63.64±12.73 for MOSART and 56.44±21.97 and 76.13±19.22 for CAST. These results show an increase from pre to post for both standard exams. Further analysis on its significance was set at 0.05 and p values less than 0.0001 were reported for both tests. **Figure 6.2** shows significant difference between pre and post MOSART.

The same was seen for CAST in **Figure 6.3**. Calculating effect size using Cohen’s d indicated large effect sizes of 0.82 and 0.95 between pre and post MOSART and CAST tests. Results on MOSART and CAST are presented in **Table 6.2.**

Table 6.2 Analysis on MOSART and CAST Standard Test.

Statistical Analyses	**MOSART (N=116)**		**CAST (N=88)**	
	Pre-	Post-	Pre-	Post-
Mean	53.03	63.64	56.44	76.13
S.D.	13.16	12.73	21.97	19.22
Effect Size	0.82		0.95	
T-Test	7.49		7.17	
P-value	<0.0001			

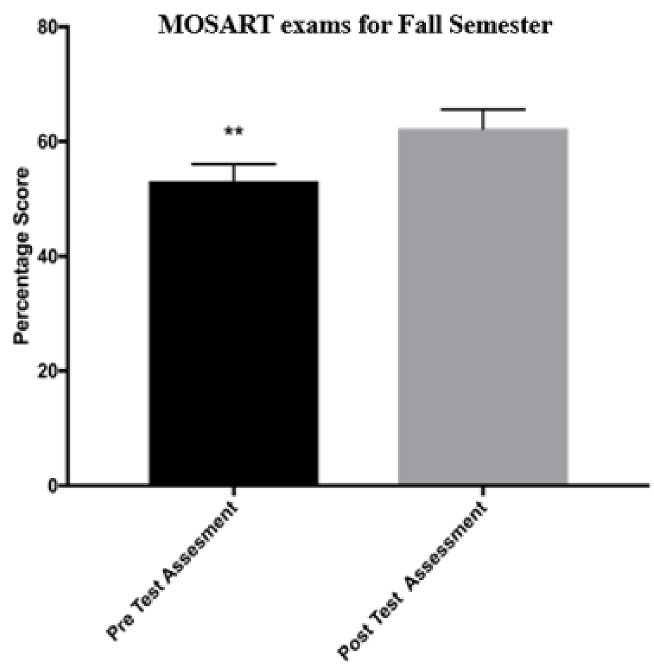


Figure 6.2. Students’ percentage scores on MOSART Test.

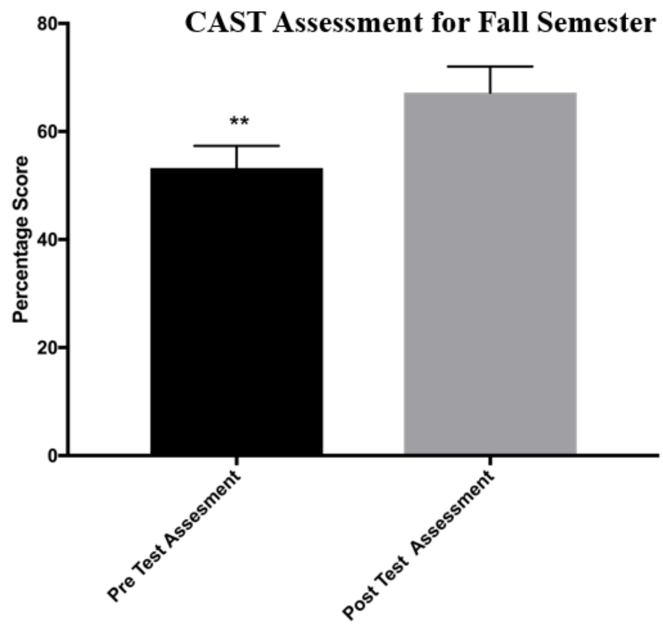


Figure 6.3. Students' percentage scores on CAST Test.

To answer the research question on student academic performance effectively, further analysis was done to investigate the impact of implemented CRCE modules on exams and ACS scores for students. This time, the scores for students who consented to participate in the study and completed the CRCE modules were compared with students who did not consent to participate. The four exams (Exams 1-4) and ACS exam were taken by both groups at the same time, and in the same manner. The total number of students for the consent group was 148 and that of the non-consent group was 54. Out of the total, a sample of 147 students from the consent group took ACS exams and that of the non-consent group was 44. For exam 1, the consent group was 148 and the non-consent group was 56. Also, 148, 148, and 140 consent students took exams 2, 3 and exams 4 respectively with 53, 50, and 54 non-consent students taken exams 2,3, and 4. No non-consent student identities were used but only their exam scores were used for such comparison where the consent was not obtained. **Figure 6.4** represent the distribution of percentage scores among the two groups (consent versus non-consent) on exam 1.

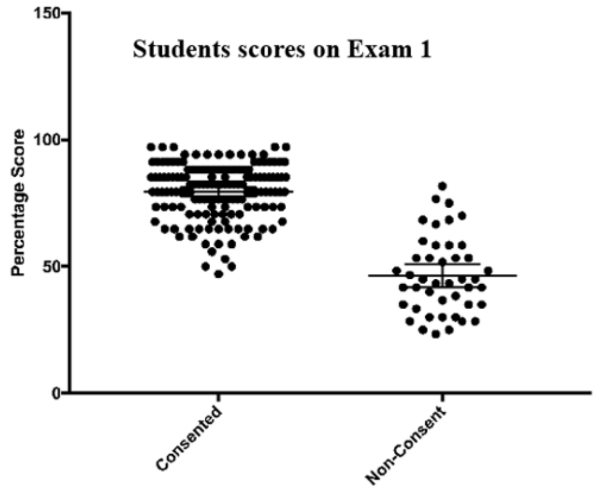


Figure 6.4. Assessment of Exam 1 Scores for Fall 2019 Semester.

The **Figure 6.5** presented below also represent the distribution of percentage scores on exam 2.

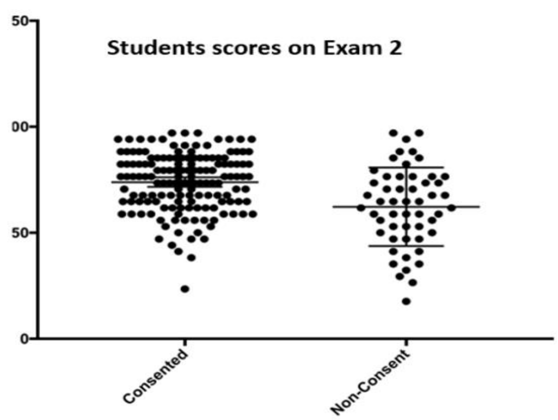


Figure 6.5. Assessment of Exam 2 Scores for Fall 2019 Semester.

The distribution of percentage scores for exam 3 and 4 among the two groups (consent versus non-consent) are shown as displayed in **Figure 6.6 and Figure 6.7**

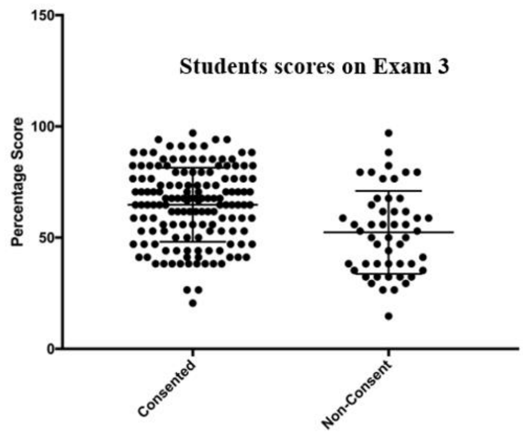


Figure 6.6. Assessment of Exam 3 Scores for Fall 2019 Semester

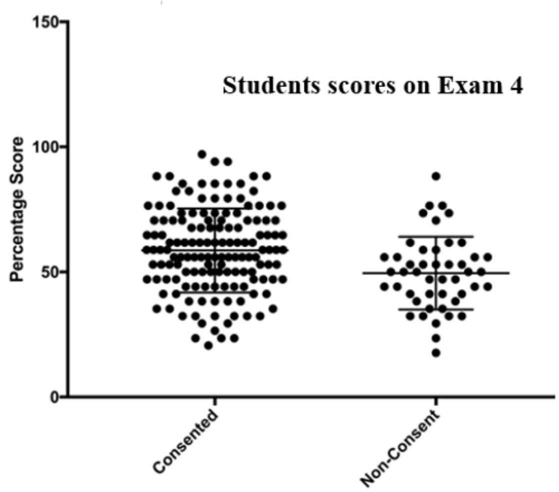


Figure 6.7. Assessment of Exam 4 Scores for Fall 2019 Semester.

Descriptive statistics were done on exam scores for both groups. The means scores with its corresponding standard deviation were calculated. An inferential statistic was done to investigate the significant difference between exam 1-4 scores for consent and non-consent groups. **Table 6.3** presents the results for both analyses.

Table 6.3. Assessment of Student Performance in Exams with implemented modules

Analysis	Exam 1		Exam 2		Exam 3		Exam 4		ACS Exam	
	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent
Mean	73.90	66.91	77.08	70.59	78.70	72.06	59.56	59.28	64.88	35.55
S. D	11.28	7.74	13.99	5.88	8.76	14.56	18.81	15.60	15.55	11.10
Effect Size	0.67		0.52		0.63		0.02		2.00	
t-Test	4.27		3.27		3.86		0.10		11.65	
Observed p-value	<0.0001		0.0013		0.0002		0.92		<0.0001	
Corrected p-value	0.01									

[1]N Exam 1-3=148, [1]N Exam 4=140, [1]N ACS=147

[2]N Exam 1=56, [2]N Exam 2=53, [2]N Exam 3=50, [2]N Exam 4=54, and [2]N ACS=44

The mean ± standard deviation for consent group on exams 1-4 and ACS exam were 73.90 ±11.28, 77.08 ± 13.99, 78.70 ±8.76, 59.56 ± 18.81, and 64.88 ± 15.55. For non-consent group, the mean ± standard deviation on exams 1-4 and ACS were 66.91 ±7.74, 70.59 ± 5.88, 72.06 ±14.56, 59.28 ± 15.60, and 35.55 ± 11.10. Since the sample sizes of the two groups were different, Hedges' g was used to calculate the effect size between the groups scores. large effect size was seen between consent and non-consent groups scores.

From results presented in **Table 6.3**, large effect sizes were witnessed for exam 1-3 and ACS exam except Exam 4. The effect sizes for exam 1, 2, 3, and ACS exam were 0.67, 0.52, 0.63, and 2.00. Exam 4 had an effect size of 0.02 between the mean scores of the two groups. The reason to this low effect size might be that, during the implementation of CRCE modules stage, modules 4 and 5 needed to be implemented before student's assessment on exam 4 because some topics were covered in the lecture at a slower pace for this exam. Students took both pre- and post quizzes on modules 4 and 5 before taken exam 4. This approach was different from the others, but a greater impact of modules on exam 4 scores was expected since all modules were implemented by that time frame**.** This observation may be attributed to some factors such as students unable to go through modules before taking the exam or students not doing well on chapters that were not covered via the modules, thereby affecting their overall performance during the exam 4.

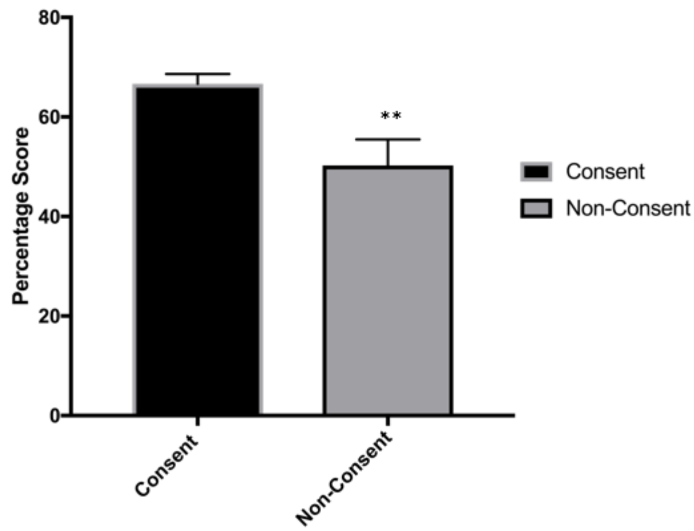
For significance testing on exam 1-4 and ACS exam between the two groups, the independent t-test studies proved a significance difference between the mean scores on exam 1 among the two groups; $\mathrm{p-value} < 0.0001, \alpha = 0.005, t\ value = 4.27, df = 202$). For exams 2 scores, significant difference $p - \mathrm{value} = 0.0013, \alpha =$

$0.005, t\ value = 3.27, df = 199$) was identified between the two groups exams mean scores at each agreeable confidence interval (Confidence Interval of 95%).

Also, studies proved a significance difference between the mean scores on exam 3 for the consent group and non-consent group. $p -$ value $= 0.0002, \alpha = 0.005, t\ value = 3.86, df = 196$). Further, when comparing mean scores for students during the ACS standard exams, a significant difference was observed between the mean values for students who consented to participate and non-consent participants in the study $p -$ value <$0.0001, \alpha = 0.005, t\ value = 11.65, df = 189$). Significant testing on exam 4 proved no significance difference between the mean scores on exam 4 among the consent group and non-consent group $p -$ value $= 0.02, \alpha = 0.005, t\ value = 0.09, df = 192$).

Results on exam 4 after the independent t-test agrees with the small effect size obtained between the groups during the analysis. Also, the descriptive analysis on consent group and non-consent group showed a minimum difference in their mean scores on exam 4. As explained earlier, this may be attributed to several factors such as students unable to go through modules before taken the exam or students not doing well on chapters that were not covered via the modules, thereby affecting their overall performance during the exam. Descriptive and inferential analyses on students' performance in exams and ACS standard exam are presented above.

In general, students' performance in post and quizzes on modules show a large effect size and statistically significant difference between their mean values for pre and post quizzes. Also, students' (consent group) performance on the two standard exams (CAST and MOSART) show a statistically significant difference between the mean scores at the beginning (pre) of the semester to the end (post). To summarize the analysis, **Figure 6.8** presents an increase in overall exams performance for students who consented when compared to the non-consent students, providing evidence on the impact of implemented modules on consent students' performance during those assessments.



P value was calculated by unpaired t-test with set significance at 0.05 at 95% CI

** Represents significance at 0.05*

*** Represents significance at 0.01*

Figure 6.8. Assessment of Total Exams Performance after Modules.

6.5.2. Student Conceptual Understanding and Cultural Awareness Via CRCE Modules

6.5.2.1. Results and Discussion of students Discussion posts for the CRCE modules

From the analysis, if a student post met the criteria for conceptual understanding it was given a score of 2, and for the conceptual mismatch or gap the student post was scored as 1. The lowest score assigned for incorrect understanding or poor conceptual understanding was 0. Concept of matter and measurements was explained in detail by students with code frequency of 297 (**Table 6.4**).

Table 6.4. Codes and representative quotations for student discussion on Module 1.

Code	Color Coding Scheme	Code Frequency-Matter and Measurement	Total Code Score
CU	Green	297	594
CM-G	Orange	143	143
IC-U	Red	26	0
R-PER	Brown	246	246
R-PRO	Blue	31	31
I-OL	Yellow	58	58

This high recorded frequency describes how students scientifically explained and defined the concepts in detail along with examples that were coherent and consistent. An example of conceptual understanding on matter and measurements would be,

The Aztecs used the scientific method when making antispasmodic medicine with the passionflower. First, they had to observe and see if other people have used it before or if animals have eaten the flower. Next, they had to research the background by asking other people about the flower. Then, they had to come up with a question asking, "How can we use this to make surgery less painful?". Next, they gave it to the patient to see if the muscles could relax. Finally, they concluded that when using the flower to make antispasmodic medicine, it relaxed the muscles during surgery so that the patient would feel less pain. We can apply concept of density when we are filling up balloons with helium, when building a boat to make sure it floats, and hot air balloons fly because they have the same density as air.

The code frequency for conceptual mismatch is 143. In this case, it means that students may have mismatched the example with the concept. Example of conceptual understanding mismatch or gap on matter and measurements would be,

This module helped me realize how advanced the Native Americans truly were. They took the scientific method and used it to help them discover things such as aspirins, anesthetics, antibiotics, and asphalt. These were all things they discovered and used in their everyday lives. *Modern America then took these theories and enhanced them using modern science and technology. A lot of things we use today can be attributed to the Native Americans and their discoveries using the scientific method.*

Student identifying the impact of matter and measurements on life explained how aside learning the concept, students value the chemistry concepts with respect to their lives outside the classroom. The code frequency for impact of matter and measurement on life is 58. Students extended their understanding in solving human needs. An example of quote on matter and measurements' impact on life would be,

This module has helped me learn a lot of new information of what the native Americans helped make happen, like medical practices that helped shape modern medicine. I also learned that the scientific method is very important when measuring things and that trial and error was used in farming and medical practices.

I found the article very interesting. I hated history in high school, but this was very interesting. I liked that they said the native American leaned everything by trial and error, thankful for them so we do not have to do it. When it came to measuring, they used their hands and feet, which is crazy to think if we still did that now, I am glad that we have the tools that we do. It would be hard to use our feet and hands all day. Back then they used *medical herbs and plants, which is wild to think about that they didn't necessarily have "pills", I wish the world now would use less pills and more herbs so we would not have such a bad opioid breakout. I liked how they were using trial and error in their everyday life.*

For module 1, students gave a depth interpretation of the concept in their personal experience and ancestral backgrounds. The code frequency was 246. From this frequency, it shows how students apply matter and measurement in their everyday applications, and to their cultural background. **Table 6.5** is an example of students' quotes.

Table 6.5. Module 1 summary of codes and representative quotations for student discussion data.

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	Our ancestors used the scientific method in many different circumstances, leading to the evolution of our scientific knowledge. A specific example of my ancestors using the scientific method was when testing the belief that the Earth was flat. An adopted misconception, the idea that the Earth was flat was based on the observations and beliefs of ancient generations. For a long time, no hypothesis was created. It was simply a fact that the Earth was indeed flat. One could argue that experimentation on this "law" at the time came in the form of travels such as Christopher Columbus, who was warned before his journey by the Catholic church that he was going to fall off of the edge of the Earth. And to the surprise of all-- he did not.	The Aztecs used the scientific method when making antispasmodic medicine with the passionflower. First, they had to observe and see if other people have used it before or if animals have eaten the flower. Next, they had to research the background by asking other people about the flower. Then, they had to come up with a question asking, "How can we use this to make surgery less painful?". Next, they gave it to the patient to see if the muscles could relax. Finally, they concluded that when using the flower to make antispasmodic medicine, it relaxed the muscles during surgery so that the patient would feel less pain. We can apply concept of density when we are filling up balloons with helium, when building a boat to make sure it floats, and

	Through experiments such as this one and even the practice of sending people out to sea to fall off of the Earth, the law that had previously been accepted by stubborn ancestors had to be analyzed. Today (most of us) know that the Earth is not flat. The scientific method does not always need to be in the same order. Because of the way the scientific method works, a scientist is going to be constantly asking questions, adjusting experiments, analyzing results, and so on. Not always in a particular order.	hot air balloons fly because they have the same density as air.
Conceptual mismatch or gap (CM-G)	If you want to perform the scientific method correctly the steps have to be followed in sequential order for it to be considered the scientific method. However, some people do not conduct experiments using the order as they should. You should always have a question before you try something, you should research it before the experiment, and while following the experiment you should document and analyze your data for a conclusion.	This module helped me realize how advanced the Native Americans truly were. *They took the scientific method and used it to help them discover things such as aspirins, anesthetics, antibiotics, and asphalt.* These were all things they discovered and used in their everyday lives. *Modern America then took these theories and enhanced them using modern science and technology. A lot of things we use today can be attributed to the Native Americans and there discoveries using the scientific method.*
Incorrect understanding/poor conceptual knowledge (I-CU)	The parts of the scientific method that I use most often outside of the classroom is making an observation and then asking a question. There are many times in a day that I wonder why the world works the way it does. Whether it is a more science related question or even just why have we as humans come up with some of the	time when my ancestors used the scientific method was when they were trying new foods. I use the scientific method in my everyday life through observation of my peers and professors.

	complex systems that we make ourselves jump through. I think the scientific method is usually used in order but can sometimes vary depending on my needs. There are times that I only use the beginning of the scientific method, such as observation and asking a question but never experiment of research to find the answer.	
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	we use measurements in everyday life to express distance. For example, I might know my house is 3 miles from the school. We apply the concept of density often. For example, when we fill up a balloon with helium, we expect it to float based on the knowledge that helium is less dense than air. The air that we breathe is in a gaseous state of matter, the furniture in our homes is solid, and the rain is liquid. We come across all states of matter in our daily lives. Density effects a lot of things in our everyday life. Swimming, balloons, and lifting objects are just a few. The example that most relates to me would be lifting different objects. If I were to need to lift a box full of bricks, I would probably have to ask for assistance because it would weight more due to having a higher density. But if I needed to lift a box full of packing peanuts of the same size, I would be able to lift it just fine. That is because	Outside of the classroom I am a barrel racer, I compete in rodeos with my horse and I use the scientific method every time I ride. I ask myself how fast can I run into my first barrel and still have a good turn? I use my background knowledge and research of the average speed I can run and how successful that is. I observe other riders and how they perform their first barrels, I conduct my own experiment AKA trial and error with how fast I can run in. And finally, I can conclude with how fast I can run in and still be successful.

	the density of the different objects is drastically different.	
Professional application (R-PRO)		
Impact on life (IOL)	The best example that comes to mind when I think about my ancestors and how they used the scientific method would be going through the process to develop healthy crop and cattle herd. Although this may only go a few generations back this is how my family made a living and were able to cultivate something amazing that one day I will get to inherit. For instance, when growing corn and alfalfa to feed our cattle herd through the winter they had to find the best fertilizers, pesticides, and irrigation systems. This was something that took years to perfect through the process of trial and error. They had to hypothesize what combination of those three things they though would work best. They then had to isolate one of those factors to form a dependent variable. Eventually they found a combination that worked best in our climate and area. I thought the module was a great way to integrate Native sciences into contemporary science since there are other forms of science that may be overlooked and not thought of as a science discipline. The Native American Sciences was a great example of how science is like second nature to us and that it is not done by people working in a laboratory with white jackets on.	This module has helped me learn a lot of new information of what the native Americans helped make happen, like medical practices that helped shape modern medicine. I also learned that the scientific method is very important when measuring things and that trial and error was used in farming and medical practices. I found the article very interesting. I hated history in high school, but this was very interesting. I liked that they said the native American leaned everything by trial and error, thankful for them so we do not have to do it. When it came to measuring, they used their hands and feet, which is crazy to think if we still did that now, I'm glad that we have the tools that we do. It would be hard to use our feet and hands all day. Back then they used medical herbs and plants, which is wild to think about that they didn't necessarily have "pills", I wish the world now would use less pills and more herbs so we would not have such a bad opioid breakout. I liked how they were using trial and error in their everyday life.

	From reading others' posts, it seems that everyone understands the concept of scientific methods and how it impacts us every day and that we don't realize that we are doing scientific method!	

In module 2, concept of chemical bonding was correctly explained in detail along with examples that are coherent and consistent with code frequency of 181 (**Table 6.6**).

Table 6.6. Codes and representative quotations for student discussion on Module 2.

Code	Color Coding Scheme	Code Frequency-Chemical Bonding	Total Code Score
CU	Green	181	362
CM-G	Orange	5	5
IC-U	Red	0	0
R-PER	Brown	103	103
R-PRO	Blue	0	0
I-OL	Yellow	160	160

From **Table 6.7**, an example of conceptual understanding on chemical bonding would be, *Ionic compounds containing (H^+) are classified as acids, ionic compounds containing (OH^-) or (0^2-) are classified as bases, and ionic compounds without either of these ions are known as salts, they can be formed by an acid-base reaction. An example of compounds interacting during a salt formation:*

Dissolving NaCl in water has no effect on the pH of a solution, therefore the solution remains neutral, this would be an example of an acid-base reaction. In this case Na is the acid and Cl are the base. The explanation behind why the solution is neutral is because the sodium and chlorine ions balance each other out creating a neutral solution

The number of times students explained the concept with gap was **5.** an example of conceptual understanding mismatch on chemical bonding would be,

Ionic Compounds that contain any hydrogen atoms are labeled as acids. When the ion is a base, it consists of hydroxide. For the ion to become a salt, the ion must become neutral or without a charge.

The code frequency of impact of chemical bonding to life is 160. This high code frequency explains how students extended their conceptual understanding to how the concept can impact life. **Table 6.7** show an example of chemical bonding on life based on students response to prompts. Also the code of students' personal application of chemical bonding is 103. This explains how students appreciate chemical bonding in their personal experience and ancestral backgrounds.

Table 6.7. Module 2 summary of codes and representative quotations for student discussion data (Fall 2019 Semester).

Code	**Representative Quotation 1**	**Representative Quotation 2**
Conceptual Understanding (CU)	Ionic compounds containing (H^+) are classified as acids, ionic compounds containing (OH^-) or (0^2-) are classified as bases, and ionic compounds without either of these ions are known as salts, they can be formed by an acid-base reaction. An example of compounds interacting during a salt formation: Dissolving NaCl in water has no effect on the pH of a solution, therefore the solution remains neutral, this would be an example of an acid-base reaction. In this case Na is the acid and Cl is the base. The explanation behind why the solution is neutral is because the sodium and chlorine ions	First you must understand how to figure out how many valence electrons an atom has, valence electrons are the electrons in the outermost shell for the main group elements. To find how many valence electrons an atom has look at its group number. When an atom is forming an ionic bond with another atom it is trying to achieve octet, meaning it is trying to fill the outermost shell with eight electrons. The atom will either loss or gain electron or electrons to match the electron configuration of the proceeding or noble gas

	balance each other out creating a neutral solution.	before it. For example, potassium has a net positive charge of one and it wants to ionically bond with oxygen that has a positive net negative charge of two. For them to form an ionic bond, you must have two potassium and one oxygen atom to have a total net charge of zero
Conceptual mismatch or gap (CM-G)	When looking at the periodic table, the number of valence electrons each element needs is at the top of the periodic table. Then between the elements you know the number of bonds based on each element filling its octet requirement	Ionic Compounds that contain any hydrogen atoms are labeled as acids. When the ion is a bas, it consists of hydroxide. For the ion to become a salt, the ion has to become neutral or without a charge
Incorrect understanding/poor conceptual knowledge (I-CU)	NA	NA
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	In my house we sometimes brush our teeth with charcoal and eat salt almost every day, which can help with hydration	It's also used in table salts which we use to cook and bake things. When I am dehydrated, I eat salty foods to help increase water retention. Without the ionic bond holding salt together, I would not be able to use this method

Professional application (R-PRO)	NA	NA
Impact on life (IOL)	Iodine is now added to table salt currently so everyone can prevent goiter. Electroplating can prevent metal oxidation (such as rust) and improve wear resistance	Hair conditioner was used to improve the feeling of hair, it also reduced friction between strands to allow for easy brushing

In module 3, concept of chemical reaction was correctly explained in detail along with examples that are coherent and consistent with code frequency of 324 (**Table 6.8).** For example**,** most students used the burning process to explain how entropy occurs. From students, burning of fire produces ashes, gases, and smoke which results in the spreading of energy (the entropy or the degree of randomness of the system). Some students also explained scientifically what chemical equilibrium is and related it to soda pop (gases in equilibrium).

Table 6.8. Codes and representative quotations for student discussion on Module 3.

Code	**Color Coding Scheme**	**Code Frequency- Chemical Reactions**	**Total Code Score**
CU	Green	324	648
CM-G	Orange	7	7
IC-U	Red	3	0
R-PER	Brown	110	110
R-PRO	Blue	0	0
I-OL	Yellow	185	185

An example of conceptual understanding on chemical reactions would be,

Spontaneous- A process that will occur without any outside interference from the system (Ice melting into water. Non-spontaneous- A process that requires outside interference *from a system to start (water does not separate into H and O without additional energy being supplied to the system.*

The number of times students explained the concept with gap was **7.** An example of conceptual understanding mismatch or gap on chemical reaction would be,

Spontaneous reaction is a forward reaction that does not use free energy. Enthalpy= Has a negative value and is the change of energy of a chemical compound or reaction. Ex. Combustion of ethanol.

The code frequency of impact of chemical reactions to life is 185. Students identifying the impact of chemical reactions to life explained how aside learning the concepts, they value the chemistry concepts in their lives outside the classroom. They extended their understanding in solving human needs. The code "Impact on Life" relates to students understanding of various concepts and examples provided by students in which they express the impact of chemistry and the content presented in CRCE modules in their lives outside the classroom. Most students showed a greater understanding of chemical reaction that occur in body for instance the process of metabolism to generate energy. This showed how students were able to expand situational knowledges to explain the chemical systems within our environment. Students extended their understanding of concepts into their personal lives with frequency 110. Example of student's quotes for personal application code are shown in **Table 6.9**.

Table 6.9. Module 3 summary of codes and representative quotations for student discussion data (Fall 2019 Semester)

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	Entropy is the measure of the amount of chaos or randomness in a system. Is the S value. e.g. campfire	Spontaneous- A process that will occur without any outside interference from the system (Ice melting into water. Non-spontaneous- A process that requires outside interference from a system to start (water does not separate into H and O without additional energy being supplied to the system
Conceptual mismatch or gap (CM-G)	A reduction chemical reaction is the transfer of electrons between species causing a molecule to lose or gain an electron in the formation of the compound	combustion reactions usually contain carbon and gas to form burning
Incorrect understanding/poor conceptual knowledge (I-CU)	Combustion is when two or more reactants come together to form one product	Spontaneous reaction is a forward reaction that does not use free energy. Enthalpy= Has a negative value and is the change of energy of a chemical compound or reaction. Ex. Combustion of ethanol.
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	In my everyday life, I use chemical reactions, energy rates, and equilibrium. Food metabolizing in my body is a chemical reaction. boiling water is an example of chemical reactions, energy rates and equilibrium in my everyday life	I use chemical reactions when cooking an egg for breakfast or having a bonfire (combustion). I use chemical equilibrium everyday with the fridge in my dorm
Professional application (R-PRO)	NA	NA

Impact on life (IOL)	Native Americans demonstrated endothermic reactions by freeze drying their food. They did this through sublimation of ice. The absence of water allowed the food to last longer	Chemical reactions are important for human needs are by digesting our food. Energy rates are important for human needs because cells cannot survive on their own. They need the energy to stay alive. Equilibrium can take place within our bodies as well relating to our body temperatures. If we are hot, we will have cool air blown on us to bring our temperature down.

Module 4 during the implementing stage was focused on the concept of solutions. Analysis of students' discussion posts in response to the discussion prompts to this module showed that students were able to conceptually explain what solution, phases of solution, and factors that affect solution. From the student discussion posts analysis, the frequency of the code relating to the scientifically correct explanation of chemical reactions was 232 (**Table 6.10**).

Table 6.10. Codes and representative quotations for student discussion on Module 4.

Code	**Color Coding Scheme**	**Code Frequency-Solutions**	**Total Code Score**
CU	Green	232	464
CM-G	Orange	63	63
IC-U	Red	20	0
R-PER	Brown	82	82
R-PRO	Blue	36	36
I-OL	Yellow	125	125

Examples of conceptual understanding would be;

A solution is a homogeneous mixture of two or more substances that interact together on a molecular and an atomic level. Some examples of a homogeneous mixture include rubbing, alcohol, bleach, and dishwater.

The frequencies of the code related to incorrect conceptual explanation or in words and they mismatch the example with the concept was 63. Example of conceptual mismatch or gap based on student post is;

Vitamin C is water-soluble because it leaves the body. It is not created in the body and is something that must be takin in through foods and supplements; they excess amounts must leave the body through urine.

Students showed how they transfer ideas from modules on solutions into the real-world scenarios. In addition to discussing the phases and intermolecular forces in solutions, students also shared the connection of these ideas and the impact on life. There were 125 instances in students' discussion wherein students discussed the relevance of solutions in terms of viewing solution as highly applicable in all disciplines of life. Students also related their understanding of solutions to their professional applications (code frequency= 36). There were 82 instances in students' discussion wherein student brought up personal applications. Summary and examples of students' quotes on module 4 are presented in **Table 6.11**.

Table 6.11. Module 4 summary of codes and representative quotations for student discussion data (Fall 2019 Semester).

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	A solution is a homogeneous mixture of two or more substances that interact together on a molecular and an atomic level. Some examples of a homogeneous mixture include rubbing, alcohol, bleach, and dishwater	Inter molecular forces aid in solubility by powering the "like dissolves like" idea. the stronger the forces between molecules, the stronger the solubility of the solute within the solvent. Vitamin C is water soluble because it is polar and contains many hydrogen bonds that are easily soluble.
Conceptual mismatch or gap (CM-G)	Vitamin C is water-soluble because it leaves the body. It is not created in the body and is something that must be takin in through foods and supplements; they excess amounts have to leave the body through urine.	A solution is a homogeneous mixture that is uniformly distributed with a solvent. Vitamin D3 is a fat-soluble vitamin and has no easy way of leaving the body.
Incorrect understanding/poor conceptual knowledge (I-CU)	The vitamin D3 is water soluble because of the C-H bonds	A solution is a mixture of 2 or more substances in a gas, liquid, or solid. Vit C is water soluble and Vit D3 is fat soluble, this be Vit D3 contain carbon atoms while the vitamin C does not.
Relevance of chemistry/ concepts to student as evidence in either in context of		

Personal application R-PER)	The ideas presented in this module can relate to my own life and everyday career because a lot of the solution examples presented can be found and used in my life daily. Along with that, the gaseous solution air, is one solution that I, and other humans breathe daily to survive. Therefore, it is very important to understand the mixing of solutions and how things such as everyday cleaning solutions can become harmful if not studied	My ancestors also used solutions and the concepts behind them to create things such as dyes and drinks. My personal ancestors would have used these concepts when they would want to can or pickle something by mixing different things in the jar like salts and water to preserve, for example, pickles.
Professional application (R-PRO)	This relates to my future career of construction management by possibly having to deal with different solutions of concrete for the foundation in different situations.	Creating solutions should not be taken lightly since the slightest error in one input can offset the entire solution. In my future career i will be mixing chemical applications for different varieties of crops and by understanding how to mix a chemical solution correctly can be very beneficial to my final yield and productivity of my farm operation.
Impact on life (IOL)	It is important to understand making solutions because it is something almost everyone deals with it daily. Mixing some substances can cause a dangerous solution which could cause a harmful chemical reaction.	We need to understand the process of making solutions to perfect our knowledge in chemistry. It is kind of like a recipe. If you mess up one area, the whole thing could be messed up too. From breakfast to supper, everything we put into our bodies is a form of a solution. Not only do I put solutions into my body it is all around in use in a day. A couple examples of this would be hairspray, makeup, and self- tanner

For Acids and bases analysis of student discussion posts in response to the discussion prompts, this showed how students were able to conceptually explain industrial and environmental applications of chemistry. From the students' posts, the frequency of the code related to the scientifically correct explanation of acids and bases was 187 (**Table 6.12**).

Table 6.12. Codes and representative quotations for student discussion on Module 5

Code	Color Coding Scheme	Code Frequency-Acids and Bases	Total Code Score
CU	Green	187	374
CM-G	Orange	0	0
IC-U	Red	0	0
R-PER	Brown	62	62
R-PRO	Blue	0	0
I-OL	Yellow	97	97

Example of conceptual understanding would be;

H2SO4 + 2KOH → K2SO4 + 2H2O. This is an acid-base reaction where a strong acid reacts with a strong base to form water and salt. This connects to what I have learned in chemistry because I know how to balance an equation, I learned about strong acids and bases, and I also learned about acid-base reactions and neutralization reactions.

There were no instances students incorrectly explained the concept of acids and bases in words or mismatched the example with the concept. Students related their understanding of acids and bases to their personal applications (code frequency= 62). Example of personal application would be;

My ancestors used acids and bases to cook and clean and for medicine. Lemons are very acidic, and a lot of the recipes passed down from my ancestors incorporate lemons. Medicine to help with heart burn are made from basic solutions, which I am sure my *ancestors used. Sulfuric acid is used to make fertilizers. My ancestors were farmers, so I am sure they utilized that. They also had to use soap to clean, which contains a base.*

Students also discussed the imprtance of acids and bases to life. The frequency of the code that related to the impact on life of acids and bases was 97. Summary and examples of students' quotes are presented in **Table 6.13**.

Table 6.13. Module 5 summary of codes and representative quotations for student discussion data (Fall 2019 Semester).

Code	**Representative Quotation 1**	**Representative Quotation 2**
Conceptual Understanding (CU)	The acid-base reaction provided is also known as a neutralization reaction. A neutralization reaction occurs when an acid and base react and form a salt and water. In this case, H2SO4 is the acid and 2KOH is the base. They react to form water and potassium sulfate which is commonly used in fertilizers.	Citric acid s a weak organic acid found in citrus fruits. It is a natural preservative and is also used to add an acidic (sour) taste to foods and soft drinks. Lactic acid is an organic acid. It is used as a synthetic intermediate in many organic synthesis industries and in various biochemical industries.
Conceptual mismatch or gap (CM-G)	NA	NA
Incorrect understanding/poor conceptual knowledge (I-CU)	NA	NA
Relevance of chemistry/ concepts to student as evidence in either in context of		

Personal application (R-PER)	My ancestors used acids and bases everyday by using water. Water has both acidic and basic traits. When making foods they used acid and bases, lemon being an acid commonly used in baking. Having an upset stomach is no fun, to relieve that my ancestors used bases to neutralize the stomach acid, such as magnesium hydroxide	For many years, my grandparents pickled vegetables and sold them for a small profit. In the process of pickling those vegetables, they used vinegar. Vinegar is an acidic acid that gives the vegetables in pickling their 'tart' taste. Ammonia, a common base is often used in agriculture. It is easy for me to believe that my ancestors used ammonia in their fertilizers for their crops.
Professional application (R-PRO)	NA	NA
Impact on life (IOL)	One of the biggest solutions to this problem is reducing carbon emission that cause the formation of these acids that contribute to acid rain. From this module I have learned that acid can be neutralized by a base. By designing a system that can incorporate hydroxide into the fossil fuel emissions from cars and factories that help neutralize the formation of these acids with water	Some things that could prevent from all the problems would be to add a base to the formula since acids and bases cancel out when looking at chemical reactions. We can also switch to solar panels and other things to reduce the pollution of fossil fuels

From students' discussion posts, it show how students showed their deeper understanding on matter and measurement, chemical bonding, chemical reactions, solutions, and acids and bases. The higher recorded frequencies for conceptual understanding code from modules show how students scientifically explained and defined the concepts in detail along with examples that were coherent and consistent. Students also elaborated on impact of these concepts to life with examples. The instances showing how students related these concepts to their professional and personal application explain how the students understood and appreciated the concepts in their everyday applications.

6.5.3. Impact on Students' Attitudes toward Chemistry

According to Bauer, attitude is a mental construct that describes a student's tendency to either react positively or negatively to the field of chemistry[4]. This study investigated the impact of implementation of CRCE modules on student attitudes using ASCI (described in chapter 4). Students pre- and post-percentage scores for attitudes after implementation of modules using ASCI subscales are displayed in **Table 6.14.**

Table 6.14. Attitude Scores for Students Enrolled during CRCE implementation in a large enrollment general chemistry survey course.

Subscale	**Pretest Scores**		**Posttest Scores %**		**p-values**	**Effect Size**
Factors	Mean	%scores	Mean	% scores		
Interest and Utility	4	53	5	64	0.0000047	0.61
Anxiety	5	70	4	53	2.135e-14	1.08
Intellectual Accessibility	3	28	4	52	0.000000083	0.68
Items						
Fear	5	69	3	38	< 2.2e-16	1.56
Emotional Satisfaction	4	51	4	55	0.001	0.41

N=135

The effect size among the pre and post was used to determine the efficacy of CRCE modules on student attitudes. The ASCI measures student's attitudes towards the subject of chemistry based on the measure of interest and utility, anxiety, intellectual accessibility, fear, and emotional satisfaction with chemistry. Detail of ASCI inventory and analysis methods are described in chapter 4.

Based on ASCI analysis of data for students who participated in CRCE modules, the fear of chemistry decreased substantially by half (large effect size of about 1.56) from the pre-test to the post-test. Anxiety also reduce to a reasonable amount, showing a large effect size value of 1.08. Student's intellectual accessibility as well as interest and utility increased significantly with moderate effect (for 135 students who participated). Student's emotional satisfaction changed significantly during the fall semester, (The largest percent of subscale values indicate students strong feeling that chemistry is "safe" and "emotionally satisfying").

Overall, CRCE modules improved the attitudes of students towards the subject of chemistry as evidenced by the ASCI data on students who participated in CRCE modules.

The overall results of the CLASS-chem survey for the general chemistry survey course during implementation of CRCE is presented below. Complete data was available from 35 students who completed the pre and the post survey. From **Table 6.15**, a strong positive % difference in shift was seen from pre to post CLASS-Chem survey.

Table 6.15. Comparison of general chemistry students' favorable responses for pre- and post-CRCE CLASS-Chem survey on student's belief in chemistry.

Survey Response Categories	Favorable Pre-survey Response (%)	Favorable Post-survey Response (%)	Difference in Average Shift (%)	Standard Error in Shift (%)
Overall	43.4	61.1	17.6	2.40
Personal interest	49.5	76.5	27.0	4.90
Real world connection	51.5	62.5	11.0	5.00
PS: general	44.4	64.8	20.4	4.20
PS: confidence	50.0	73.5	23.5	5.70
PS: sophistication	25.5	64.7	39.2	4.50
Sensemaking/effort	53.9	63.9	10.0	3.70
Conceptual connections	30.1	55.9	25.8	4.90
Conceptual learning	22.0	45.5	23.5	4.10
Atomic-molecular perspective of chemistry	48.9	90.2	41.3	4.40

Note: N=35

All Students % favorable pre and post scores for all categories of attitudes show positive shifts. Difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were 27.0%, 11.0%, 20.4%, 23.5%, 39.2%, 10.0%, 25.8%, 23.5%, and 41.3%, respectively. From the analysis, it was seen that students who participated general conceptual learning, atomic-molecular perspective of chemistry, and PS: sophistication increased about two-folds. Same positive shifts were seen when attitudes of women in the course were analyzed. Positive shifts in all categories were witnessed. Difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were 22.0%, 5.7%, 14.0%, 19.3%, 38.9%, 2.8%, 24.0%, 25.3%, and 34.8%, respectively. From results, it was seen that female students who participated general conceptual learning, and PS: sophistication increased about two-folds (**Table 6.16**).

Table 6.16. Comparison of general chemistry women favorable responses for pre and post CRCE-CLASS-Chem

Survey Response Categories	Favorable Pre-survey Response (%)	Favorable Post-survey Response (%)	Difference in Average Shift (%)	Standard Error in Shift (%)
Overall	48.6	61.6	13.0	2.70
Personal interest	54.5	76.5	22.0	5.90
Real world connection	60.2	65.9	5.70	4.50
PS: general	51.6	65.7	14.0	4.70
PS: confidence	60.2	79.5	19.3	6.40
PS: sophistication	27.1	66.0	38.9	6.20
Sensemaking/effort	59.6	62.4	2.8	4.60
Conceptual connections	35.5	59.5	24.0	6.70
Conceptual learning	21.0	46.3	25.3	5.40
Atomic-molecular perspective of chemistry	56.1	90.9	34.8	5.60

Note: N=23

Also, same analysis conducted on 12 male students who participated showed an increase in all categories for attitudes assessment. Difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were 20.8%, 11.0%, 10.8%, 12.6%, 19.5%, 4.6%, 9.4%, 8.7%, and 15.3%, respectively (**Table 6.17**).

Table 6.17. Comparison of general chemistry males' favorable responses for pre and post CRCE-modules.

Survey Response Categories	**Favorable Pre-survey Response (%)**	**Favorable Post-survey Response (%)**	**Difference in Average Shift (%)**	**Standard Error in Shift (%)**
Overall	39.2	47.6	8.40	1.90
Personal interest	39.1	59.9	20.8	3.70
Real world connection	45.2	59.9	11.0	3.90
PS: general	42.5	53.3	10.8	3.30
PS: confidence	54.4	66.9	12.6	4.70
PS: sophistication	30.7	50.2	19.5	3.40
Sensemaking/effort	45.2	49.8	4.60	3.00
Conceptual connections	32.0	41.4	9.40	3.40
Conceptual learning	27.0	35.6	8.70	3.30
Atomic-molecular perspective of chemistry	45.0	60.3	15.3	4.40

Note: N=12

These analyses showed that attitudes of both men and women were consistently found to be like that of a chemist. All categories showed positive shifts for all analyses, evidencing the impact of implementation of CRCE modules on students' attitudes.

6.5.4. Impact of CRCE implementation on Student Motivation and Self- regulation.

The **Table 6.18** presents the Impact of module implementation on students' motivation and self-regulation.

Table 6.18 Impact of CRCE modules implementation on students' motivation and self-regulation during the Fall 2019 semester.

SALE Survey (Category)	Pre-SALE Response		Post-SALE Response		Paired-t-test value	p-value
	Mean	S.D.	Mean	S.D.		
LGO	3.88	0.60	4.80	0.30	-7.32	<0.00001
TV	3.63	0.67	4.12	0.62	-4.93	0.00003
SE	3.69	0.73	4.13	0.61	-3.77	0.00071
SR	3.52	0.62	4.21	0.51	-4.07	0.00032

Categories mean and standard deviation values were calculated and the mean scores for each of the four SALES categories were compared using paired sample t-test. An increase in mean value with significance from the pre to post was witnessed for all the four categories. There was a shift in students LGO mean ± standard deviation from pre (3.88 ±0.60) to post (4.80 mean ± 0.30). Pre mean ± standard deviation for TV, SE and SR were 3.63 ± 0.67, 3.69 ± 0.73, and 3.52 ±0.62, respectively. At the post, the mean values increased (TV, SE, and SR were 4.12± 0.62, 4.13 ± 0.61, and 4.21± 0.51, respectively. Analysis on all four SALES categories show an increase in mean values, and further analysis on mean scores for the four categories set at 0.05 showed significant difference between the pre and post for the categories. Significant differences between pre and post LGO mean values (p value <0.00001), TV (p = 0.00003, SE (p-value = 0.0071, and SR (p = 0.00032) existed. positive shifts in mean values show an impact of module implementation on all categories (Leaning Goal Orientation, Task Value, Self-Efficacy, and Self-Regulation) used in assessing students' motivation and self-regulation.

Also, the cumulative score for each factor in the SALES was calculated for each of the 32 items under the 4 categories. Increase in number of students who were highly motivated in this study indicate students having strong ability and confidence to perform and regulate the task of understanding the concepts presented in the CRCE modules. There was a positive shift (from 17 to 30) in number of students who had high Learning Goal Orientation from the pre to the post. At the beginning of the semester, 17 (55%) students had high Learning Goal Orientation, but this number increased to 30 (97%) at the end of the semester. The remaining students had acceptable LGO. At the end of the semester, no student perceived him/herself not to be participating in the assigned chemistry task.

Same results were witnessed for task value. The number of students who had higher task value increased from 9 to 21 from the beginning to the end of the semester, showing student's appreciation to perform the assigned task.

Under Self-Efficacy, there was a positive shift in number of students with high self-efficacy from 9 to 18. The percentage of students who had high confidence and believes in their capabilities in successfully performing the assigned tasks increased 29% from the pre to 58% for the post.

Self-Regulation category also showed an increase in number of students with high self-regulation. The number of students with high self-regulation increased 13(42%) from the pre to the post 20(5%). This explains that the degree to which the students were regulating and controlling their efforts in the chemistry content learning was high. This analysis on attributes of motivation and self-regulation is displayed in **Figure 6.9**. From the results, it shows that implementation of CRCE modules positively shifted student motivation and self-regulation for learning chemistry.

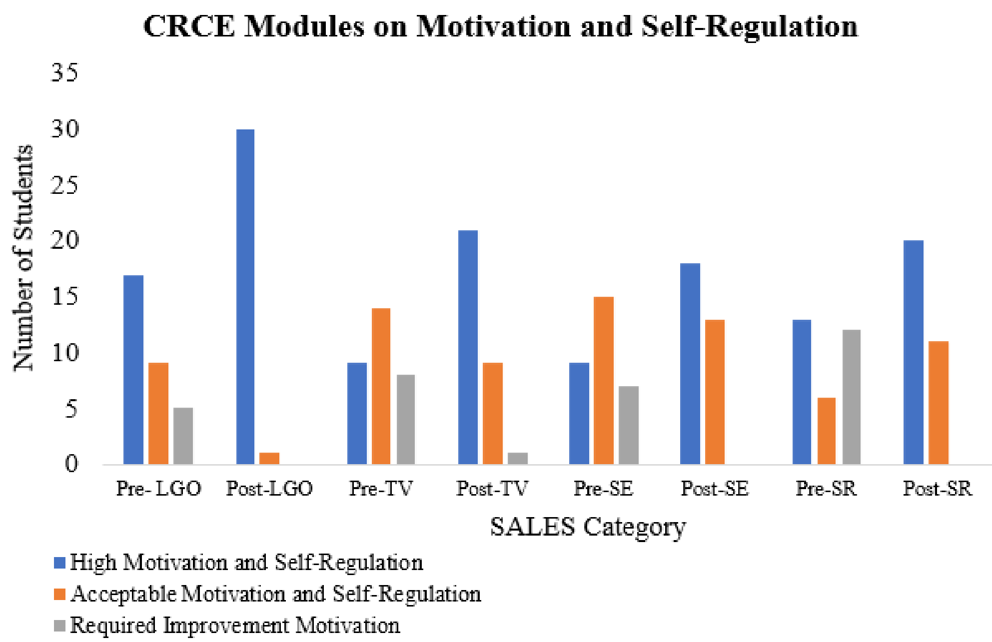


Figure 6.9. CRCE Implementation impact on Motivation and self-regulation.

6.5.5. CRE Survey Analysis

The CRE survey was done at the end of semester to address student perception and experience of CRCE modules. A total of 42 responses were obtained from students who completed post CRE survey. Items in this survey focused on the importance of chemistry, and some items were also focused on the use of modules (**Appendix 16**). **Table 6.19** provides survey items and students' mean and percent responses along with frequency of student responses on this Likert Scale survey.

Table 6.19. Summary of student responses to CRCE survey items.

Items	Mean	S.D.	%(N) Strongly agree	% (N) Agree	%(N) Neither agree nor disagree	%(N) Disagree	%(N) Strongly Disagree
1	4.20	1.30	33(14)	48(20)	14(6)	2(1)	2(1)
2	4.87	0.35	48(20)	33(14)	17(7)	2(1)	0(0)
3	4.53	0.64	40(17)	50(21)	5(2)	5(2)	0(0)
4	4.50	0.0.71	40(17)	50(21)	10(4)	0(0)	0(0)
5	4.00	0.00	19(8)	64(27)	7(3)	10(4)	0(0)
6	4.00	0.00	17(7)	60(25)	12(5)	12(5)	0(0)
7	3.88	0.60	14(6)	55(23)	12(5)	19(8)	0(0)
8	4.1	0.32	10(4)	67(28)	10(4)	10(4)	2(1)
9	4.00	0.00	10(4)	55(23)	19(8)	14(6)	2(1)
10	3.75	1.26	7(3)	43(18)	31(13)	19(8)	0(0)
11	4.00	1.10	14(6)	62(26)	17(7)	7(3)	0(0)
12	4.00	0.00	10(4)	57(24)	24(10)	10(4)	0(0)
13	4.00	0.00	12(5)	48(20)	24(10)	12(4)	5(0)
14	3.50	0.55	19(8)	57(24)	17(7)	5(2)	2(1)
15	3.85	0.38	19(8)	67(28)	14(6)	0(0)	0(0)
16	4.69	0.60	55(23)	33(14)	12(5)	0(0)	0(0)

The mean ± standard deviation of CRE survey 16 items was 4.12 ± 0.48. Based on the analysis of CRE survey, it was found that about 48% (20) students strongly agreed that studying chemistry help them gain knowledge that will be useful in their lives outside college. 33% (14) strongly agreed, and 17% (3) chose neutral for this question. Only one student out of the 42 disagreed to this statement. A total of 40% (17) students strongly agreed, and 51% (21) agreed that studying chemistry really changes their ideas about how the world works. When students were asked if the knowledge in chemistry is made up of several related topics that build on each other, more than half of the students 64% (27) replied they agree. 10% (4) students disagreed to this item. None of the students strongly disagreed to this statement.

In assessing how students perceive chemistry application to everyday life and to that of culture, 40% (17) students strongly agreed, and 51% (21) agreed that they find chemistry applicable to their everyday lives. With respect to conceptual understanding, 60% (25) students agreed it basically means one must be able to recall or connect it with what they practice or experience in their everyday life.

Regarding the use of CRCE modules, more than half of the students 57% (24) agreed that the relationship between indigenous or traditional practices and modern scientific approaches represent a continuum of scientific knowledge. Students who agreed that knowledge and use of chemistry in daily life is also part of their cultural heritage were 28. About 57% (24) students elaborated that the use of indigenous or cultural knowledge in CRCE modules increased their intellectual curiosity and desire to study chemistry. Also regarding the benefits of using CRCE modules, 55% (23) strongly agreed, and 33% (14) agreed that they would like to see more modules and resources in chemistry that make use of examples connecting cultural practices with modern science.

6.5.6. Students Experience with CRCE Modules

Students were purposefully sampled for semi-structure interviews based on their participation in CRCE modules. Students interview analysis followed an inductive path, which allowed several codes to emerge from the interview data. Among students who were interviewed, 7 were majoring in nursing, 1 in construction management, 1in human development and family studies, and 1 in Agronomy. All respondents were Caucasians. 1 out of the 10 was a sophomore. The remaining students were freshmen. In the interview, students shared their experience with learning science as a student. Majority of the students

(9 respondents) who were interviewed shared how they are progressing in learning science from high school to college. Eight of the students explained how they learned basic science in high school and how now learning science in college is more in-depth. Example of students' quotes on their experience with learning science is.

In high school it was okay. I did not really have teachers that took it seriously. I just took it to graduate. In college it was different because the teachers cared and were there to teach you and you must absorb the material. And I am okay at chemistry. It has never been hard for me. I came into it and it was challenging but I liked it. Well I took chemistry my sophomore year of high school but I kind of forget so I learned it, but I did not really remember it. This is the first chemistry class I have taken since then. So, I kind of forget everything so walking into chem 106 I was trying to relearn everything.

Students talked about their initial feeling coming to learn chemistry. For this question, most students (N=9) talked chemistry being difficult before enrolling in the class (CRCE modules). Example of students quote on their feeling coming to learn chemistry is.

I do not know. I thought it was kind of hard. I was terrified

Students also found concepts from CRCE modules like chemical reactions very interesting. Overall, 9 students mentioned concepts that were covered in the modules to be interesting. Example of quote is.

I would say the chemical reactions. Those are always good. That always went well. Converting too went well because of the knowledge I had. Everything really was good for me. Everything on the last exam was a little hard and I was not confident in that and so that was hard.

Mole of a substance was mentioned by one student who saw it very interesting. This concept was not covered in the modules. The student answered.

I like the moles more so than the acids and bases because that's one of the only ones I remember from high school, so I kind of had an idea going in and everything else was kind of new so I was never really confident with it. I liked the periodic table. I guess it is just easy to understand, so I do well with that one.

Students were asked whether they make connections between their learning from CRCE modules and chemistry in general with their everyday activities. Among the respondents, 9 students answered that they do not make any connection unless the concept is very specific, but after they went through the modules, now they do. Example on how students do not make any connection unless the concept is very specific is.

Not really. Like I said I kind of came in blindsided so when we did the modules it really helped me understand what was being applied, what we were going to learn, how to do it stuff like that. When we were in high school, we did not really go over how things relates. We always asked how it relates and they always said well you just need to know it.

Students' knowledge of cultural practices and traditional applications of chemistry before they experienced the modules were assessed. All the 10 respondents said they had no knowledge on traditional applications of chemistry before their participation in the CRCE modules. Example of quotes are.

Not really. Like I said I kind of came in blindsided so when we did the modules it really helped me understand what was being applied, what we were going to learn, how to do it stuff like that.

No, I had no knowledge of cultural practices and traditional applications of chemistry before taken this class.

Probably very little when I did the modules. It probably helped with the broad concepts. It helped me understand those better.

When students were asked about the advantages of learning about chemistry from a cultural standpoint, two students said it gives one different idea on how things are done in the world. Six students said it helps one to understand and appreciate that there is chemistry in everything we do. A student answered that learning chemistry from the cultural standpoint makes it interesting and relevant. Examples of quotes showing students answers on the advantages of chemistry from cultural standpoint are.

I think advantages are being able to understand that there is chemistry through everyone is lives all the time and there's chemistry around you all the time in everything you do and with products. You can really apply it and it can help you better understand where its coming from. Like chemistry is not something that somebody just made up. It is in everyday life. It is not just in a textbook.

It gives a new perspective on life. Like everyday things you do not really think about. And then you go through chemistry and you are like oh there is a chemical reaction or that is why my body does that. I liked it because it like gave it a different view on like the chemistry so it actually kind of interested me more than in class because I actually got to apply it and learn about the culture.

For difficulty rate of modules, 50% of the students rated the module as easy while two respondents rated the modules as difficult with further explanation that the module text files were a lot to read. Three students answered that they neither see the modules as easy nor difficult. There was no further question asking students as to why they rated the modules in that manner. From the interview data, it showed how with the help of modules, students can make connections between their learning chemistry in general with their everyday activities, and their awareness of knowledge of cultural practices and traditional applications of chemistry were impacted through implemented modules.

6.6. Conclusion for CRCE Implementation

This chapter described the impact of implementation of modules on student academic performance, conceptual understanding, student attitudes about the subject of chemistry, and motivation and self-regulation. Based on comparison of student mean scores, it was found that students who participated in CRCE modules showed a significant improvement in hour exams 1, 2, 3, ACS, quizzes on modules, MOSART, and CAST tests. Significant difference was witnessed between pre and post MOSART (*p value* <0.0001), CAST with *p value* <0.0001, and pre and post quizzes 1-5 with *p value*s<0.0001, and exam scores for 148 students (consent group) and 54 (non-consent group) From results, large effect size was witnessed for exam 1-3 and ACS exam except Exam 4. The effect sizes for exam 1, 2, 3, and ACS exam were 0.67, 0.52, 0.63, and 2.00, respectively. Exam 4 had an effect size of 0.02 between the mean scores of the two groups which this observation may be attributed to some factors such as students unable to go through modules before taking the exam or students not doing well on chapters that were not covered via the modules, thereby affecting their overall performance during the exam 4. Further, comparing mean scores for students who consented versus students who did not consent for the study during the ACS standard exams, a significant difference was observed between the mean values for students who participated in the study $p-$value $<0.0001, \alpha=0.005, t\ value = 11.65, df=189$). These results show the impact of modules on consent students' academic performance in the course. It is good to address that the, non-consent group might have benefited from the instruction of module content and examples that were used in the lecture though they had no requirement of using the modules or participating in the module pre and post quizzes. These assessments were optional for students and did not impact their course grade.

Students conceptual understanding was evaluated using student discussion prompts. Analysis on discussion presented frequencies and student scores for the codes related to conceptual understanding which show greater number (CU= 297 for matter and measurements, CU= 181 for chemical bonding, CU= 324 for chemical reactions, CU= 232 for solutions, and CU= 187 for acids and bases). These numbers showing conceptual understanding is higher when compared to students showing conceptual mismatch for each module during the implementation stage (CM-G= 143 for matter and measurement, CM-G= 5 for chemical bonding, , CM-G= 7 for chemical reactions, , CM-G= 63 for solutions, and , CM-G= 0 for acids and bases). Another code that came out from students posts also showed how students were relating these concepts to their everyday applications and ancestral backgrounds. The number of times students referred to their personal application of the concepts of the matter and measurement, chemical bonding, chemical reactions, solutions, and acids and bases were 246, 103, 110, 82, and 62, respectively. Also, students also showed how these concepts impact lives. The number of times students explained how concepts of matter and measurement, chemical bonding, chemical reactions, solutions, and acids and bases impact lives were 58, 160, 185, 125, and 97, respectively As explained ealier, the discussion prompts were mainly guidelines and that the students were not required to respond to every prompt. From the results, student conceptual understanding was impactful through implementation of modules, considering that students used examples from modules and tied the concepts to their personal and professional aspects of life including their background and ancestry.

From CLASS-Chem analysis, student's attitudes show positive shifts in categories for assessing attitudes over the course in the CLASS-Chem survey. CRCE modules were highly successful at achieving the goal of improving in general students' personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry with difference in average shift of 17.6%, 27.0%, 11.0%, 20.4%, 23.5%, 39.2%, 10.0%, 25.8%, 23.5%, and 41.3%.

Also, ASCI analysis showed a decrease in fear and anxiety for students who participated in CRCE modules with effect size of 1.56 and 1.08. Student's intellectual accessibility, interest and utility increased significantly with moderate effect for the students who participated. For student's emotional satisfaction, it changed significantly during the fall semester. Overall, the analyses showed implemented modules to improve the attitudes of students towards the subject of chemistry as evidenced by the ACSCI and CLASS-Chem data on students who participated in CRCE modules.

Results for analyzing student motivation and self-regulation also show an increase in mean value with significance from the pre to post as witnessed for all the four categories.

There was a shift in LGO mean ± standard deviation from pre (3.88 ±0.60) to post (4.80 mean ± 0.30), and the pre and post mean ± standard deviation for TV, SE and SR also showed positive shifts from 3.63 ± 0.67, 3.69 ± 0.73, and 3.52 ±0.62, to 4.12± 0.62, 4.13 ± 0.61, and 4.21± 0.51. Also further analysis on mean scores for the four categories set at 0.05 showed significant difference between pre and post LGO mean values (p value <0.00001), TV (p-value= 0.00003, SE (p-value = 0.0071, and SR (p-value = 0.00032). These positive shifts in mean values with significance show an impact of module implementation on all categories (Leaning Goal Orientation, Task Value, Self-Efficacy, and Self-Regulation) for assessing students' motivation and self-regulation.

To investigate students' experience with CRCE Modules, CRE survey show how about 48% (20) of students strongly agreed that studying chemistry help them gain knowledge that will be useful in their lives outside college. Aside that, a total of 40% (17) students strongly agreed and 51% (21) agreed that studying chemistry really changes their ideas about how the world works. Regarding the use of CRC modules, more than half of the students 57% (24) agreed that the relationship between indigenous or traditional practices and modern scientific approaches represents a continuum of scientific knowledge. From CRE survey data, it showed how students elaborated on the benefits of using CRCE modules and would like to see more modules and resources in chemistry that make use of examples connecting cultural practices with modern science.

Also from interview data, it shows how with the help of modules, students can make connections between their learning chemistry in general with their everyday activities, and how their awareness of knowledge of cultural practices and traditional applications of chemistry were impacted through implemented modules. Therefore, to ensure continued high academic performance, conceptual understanding, attitudes, and motivation in the subject chemistry, chemistry instruction should relate to basic chemical principles to the everyday experiences of the student.

Although these analyses were conclusive of CRCE modules impacting students' academic performance, conceptual understanding, attitudes, motivation and self-regulation, there was still the need to assess the impact of CRCE modules integration in a large enrollment face-to-face section of the general chemistry survey course. For instructors engaging in efforts to implement these modules and develop more modules, these data point to several approaches that may benefit those efforts. Studies on integration of CRCE modules in a course is presented in the next chapter (**Chapter 7**).

6.7. References

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CHAPTER SEVEN

INTEGRATION OF CULTURALLY RELEVANT CHEMISTRY EDUCATION (CRCE) IN A LARGE ENROLLMENT CLASSROOM

7.1. Introduction of Integrated CRCE Modules

Science teaching and learning is experiencing a huge shift with the emergence of student-centered technologies that are now being used in sync with student-centered pedagogies such as inquiry-based learning[1,2]. Chemistry education is seeing a gain in the increased use of you-tube videos, simulations and visualizations for advancing student learning[3, 4]. There is a greater need for curricular materials that enable students to become aware of both the subject matter and their own life and cultural experiences. An increase in the knowledge and awareness is fundamental for developing scientifically literature citizens who can manipulate their environment in rational terms to reap the fruits of their rich cultural resources. This has resulted in the need for the college chemistry instruction to utilize vast resources of the society that provide real and meaningful experiences and learning opportunities for the students[5]. Klopper in 1969 suggested two components of scientific literacy as understanding of [5],

1. the relation of science to culture and the relation between the science and the related technologies on contemporary society.
2. the key components and principles of "survival science" which are related to one's life.

In appreciation of these two tenets of scientific literacy, CRCE study emphasized the introduction of modules to not help students acquire the knowledge of their environment, but also impact their academic performance, conceptual understanding, attitudes, and motivation and self-regulation in chemistry. In this chapter, the developed modules were integrated in the course in the spring 2020 semester. The purpose of integration of CRCE modules in course was to assess the impact of integrating developed modules in the course after the pilot and implementation stages on students' academic performance, conceptual understanding, attitudes, and motivation and self-regulation toward chemistry and their learning environment. The integration stage of CRCE meant that the modules were completely integrated in the course syllabus as a requirement for all students. In addition to course text, the module texts and videos were required for all students to watch and these were compulsory part of student assessment in the course. In the pilot and implementation stage, student participation was voluntary. In the integration stage, because the CRCE was made part of the syllabus component all students had to use the modules and prepare for the course using modules and the text. The modules were covered also in lecture in depth. Prior to integration stage the examples for modules and discussions were done by instructor in the lecture too, but in the implementation stage all students were not required to read the module texts and the videos posted on D2L to prepare for the course content.

7.2. Research Questions for the Integration of CRCE Modules

CRCE integration focused on similar research questions as the first two stages: (a) Does integration of developed CRCE modules impact the academic performance of students in general chemistry? (b) Does integrated CRCE modules impact the conceptual understanding and cultural awareness of student enrolled in the course modules were implemented? (c) What is the impact of integrated CRCE modules on students' attitudes toward the subject chemistry? Moreover, are there any differences between students' attitudes towards the subject chemistry? (d) Does integration of CRCE modules impact undergraduate students' motivation and self-regulation in learning chemistry?

7.3. Integration of CRCE Modules

7.3.1. Study Setting

The research setting remained the same in the integration stage. The CRCE modules were implemented in a large enrollment section of the general chemistry survey course at South Dakota State University.

General chemistry class size typically ranges from 120-350 students. CRCE modules were integrated into the course at the beginning of the spring 2020 semester. Module for a particular concept formed one-third of lecture material when covering that concept. For example: contextual analogies from chapter 1 of module was integrated into lecture materials when teaching the class matter and measurements. This happened for all the 5 CRCE modules. The CRCE module material was completely integrated in the classroom instruction with the rest of the chemistry topics.

It is important to note during the integration stage, it was planned to conduct video-based classroom observations for the integration of all module in the course. Video observation during lecture hours was not conducted for the entire course due to COVID-19. This data was dropped from consideration.

7.3.2. Participants

Overall, there were 208 students in total who enrolled in the general chemistry survey course during the spring 2020 semester. Among these, 5 students later dropped the class, resulting in a final sample of 203.

Their data were not considered for further analysis. Students demographics are presented in **Table 7.1**. All students enrolled in the course participated in the lecture-based instruction with integrated modules. When course was moved online due to COVID in the middle of semester (March) students received asynchronous instruction through D2L where the course instructor continued to use the modules and the text for instruction of various topics. Student consent was obtained for collecting data for the study of CRCE modules at the integration stage.

Table 7.1. Students Demographic (Spring 2020).

Demographic Variables	Number of students (%)
Overall	203
Consent participants	158 (78%)
Gender	
Female students	73 (46%)
Male students	85 (54%)
Year/Level	
Freshmen	126 (80%)
Sophomore	27 (17%)
Junior	5 (3.2%)
Senior	0 (0%)
Ethnicity	
Caucasian	144 (91%)
Black/African American	4 (3%)
Asian	2 (1.3%)
Hispanic/Latino	1 (1%)
Germanic	1 (1%)
Native American	5 (3%)
Mexican	1 (1%)
Major	
Agricultural sciences	87 (55%)
Social sciences	6 (4%)
Health sciences	29 (18%)
Other majors	36 (23%)

7.3.3. Data Collection

7.3.3.1. Integrated CRCE modules on academic performance

In this part of data collection, students' academic performance was the metric to be evaluated. Data were collected from students (N=158) for the two standard exams (Misconception Oriented Standard-based Assessment Resource for Teachers (MOSART) test, and California standard test (CAST) at the beginning and end of semester. Details of these two standard exams can be found in **Chapter 4**.

For the spring general chemistry survey course, 5 multiple choice exams were administered at four-week intervals, including one final comprehensive exam. The first four exams were not comprehensive (hour exams covering fewer topics). Example of exam questions can be found in the **Appendix**.

Due to COVID, the ACS standard exam data was not collected during the integration phase. There was an option of online exam, but the challenge with using the general chemistry online test was that it did not capture the content in the same way as the general chemistry exam for the general, organic and biochemistry sequence ACS exam of 2014 version did. To address this challenge the course instructor developed an online exam on the Pearson Mastering Chemistry which captured the same kind, depth, and rigor of questions as the ACS standardized exam for GOB general chemistry test. This cumulative online exam had 60 questions like the ACS standard exam that was used during the implementation stage. The online, timed exam was used as a cumulative final assessment to evaluate student academic performance for the course for the integration of CRCE modules.

For assessing student understanding of the CRCE modules, 10 multiple choice questions were set for each module. A pre quiz covering all modules was administered at the beginning, followed by quiz for each module, then a comprehensive quiz covering all modules concepts was given before students took the last exams. More details on how modules and quizzes were developed, and modules channeled into videos and texts can be found in **Chapter 3.**

7.3.3.2. Integrated CRCE modules on conceptual understanding

Qualitative data for assessing the conceptual understanding of students was also collected from student D2L discussion posts. After the professor in charge of the class covered each chapter in lecture with integrated modules covering the same concepts, students were asked to discuss these topics based on discussion prompts for each topic (see Appendix for examples of discussion prompts). Discussion posts from 72 students after integration of each module were collected and analyzed.

7.3.3.3. Integrated CRCE modules on student attitudes

Students' attitudes toward chemistry was evaluated through the Attitude toward the Subject of Chemistry Inventory (ASCI)[6]. This survey evaluates students' attitudes toward chemistry along five variables: Interest and utility, intellectual accessibility, emotional satisfaction, anxiety, and fear[6]. Colorado learning attitudes about science survey (CLASS-Chem) was also used to measure students' attitudes toward chemistry (categories for attitudes include; Personal Interest (PI), Real World Connection(RWC), Problem

Solving General(PSG), Problem Solving Confidence(PSC), sophistication (S), Sense Making/Effort(SM), Conceptual Connection(CC), conceptual learning(CL), and atomic-molecule perspective of chemistry categories)[7]. Further information on CLASS-chem survey can be found in the papers by Perkins et al[8].

7.3.3.4. Integrated CRCE modules on motivation and self-regulation

Student’s Adaptive Learning Engagement in Science survey was used to measure impact of integration of CRCE modules on student’s motivation and self-regulation. Factors in SALES survey that measure motivation and self-regulation are learning goal orientation (LGO), Task Value (TV), Self-Efficacy (SE), and Self-Regulation (SR)[9]. **Chapter 4** provides details of the SALES survey. All instruments are reliable and valid.

7.3.3.5. Students experience with Integrated CRCE modules

Toward the end of the CRCE modules, Culturally Relevant Education (CRE) survey was administered to investigate student’s perception of modules and know whether students found CRCE modules to be useful for learning of chemistry. Details of the survey can be found in **Chapter 4**. The surveys involved a 5-point Likert Scale.

A selected number of students were called for interview. Interview sessions were conducted via zoom to gather qualitative data on student’s ability to transfer and incorporate scientific knowledge from the CRCE modules. Interview protocol can be found in **Appendix**. A total of 20 students were interviewed.

The initial plan was to administer some surveys at the beginning and end of the semester through pencil and paper format, but all post surveys for the spring semester were taking online due to the temporary shutdown of the institution due to COVID-19.

7.3.4. Data Analysis

All data sets were cleaned and processed as per the quantitative and qualitative data handling procedures before data analysis took place. For consistency, students who answered both pre-and post-surveys were included in the study. It was ensured that assumptions were met for all the statistical tests employed in the analyses of the data. Following presents how each data set was analyzed.

7.3.4.1. Assessment of Student Academic Performance

All CAST, MOSART, 5 exams, and quizzes on modules were transferred to excel file from the D2L and were analyzed using parametric and non-parametric approaches. Student academic performance was assessed using student scores in both pre- and post-CAST, MOSART, quizzes, and 5 exams for which the mean, and standard deviation were calculated. Also, difference in exam scores (exam 1-5) between students who further read module files, watched videos aside its integration in course, took quizzes and standard tests, and students who did not do any of these were investigated. For the sake of analysis, these two groups were labelled as consent and non-consent groups. During significance testing, statistical significance was set at 0.05 and p values were reported for all tests. Further analyses were done to test the effect size of CRCE integrated modules on academic performance. The percentage scores for students were used for studying the impact of CRCE modules on academic performance.

7.3.4.2. Impact of Implementation of CRCE modules on Conceptual Understanding

To address the impact of integrated modules on student conceptual understanding, students' discussion posts on D2L were used to assess student conceptual uderstanding. Student posts were scored on a point scale based on the accuracy of student explanations and examples included in student discussion posts. The coding process followed similar protocols and procedures as described in **Chapter 5 and 6**. The coding scheme developed during the piloting stage which was again applied during the implementation stage was used in the integration stage to maintain consistency for coding and scoring the student posts. About 72 students answered D2L discussion prompts on all the five modules. The six codes were: Conceptual Understanding, Conceptual mismatch or gap, Incorrect understanding/poor conceptual knowledge, and relevance if chemistry (subcategories under relevance of chemsitry were personal application, professional application, and impact on life). The following are the definitions of each code.

9. **Conceptual understanding (CU)** includes – scientifically correct explanation and definition of concept in detail along with examples that are coherent and consistent.
10. **Conceptual mismatch or gap (CM-G)** means that students are not able to correctly tie the concept or explain it in words and they mismatch the example with the concept, or their explanation lacks details along with example. There is an apparent inconsistency in student response as compared to the scientifically correct conceptual explanation. Some coherence in statement of concept and example.

11. **Incorrect understanding/poor conceptual knowledge (I-CU)** There is essentially a complete lack of understanding in response in discussion and student is not showing any coherence between statement of concept and example.

12. **Relevance of chemistry/ concepts** to student as evidence in either in context of:

a) **Personal application (R-PER):** Student provides examples in response to discussion prompts that are more personal in nature for example – brushing teeth or walking to class or things done in and around home.

b) Professional application (R-PRO): student provides examples in response to discussion prompts that are more professional oriented for example job, career, or work settings.

c) Impact on life (I-OL): Student sees big picture and provides examples in discussion in terms of how the chemistry impacts environment, life, human body, sustainability, industry, a certain field etc.

ATLAS.ti program was used to identify the code frequency to see the code recurrence during the coding of student discussion posts. A color coding scheme was used to generate a frequency of these codes as presented in results.

7.3.4.3. Assessment of CRCE Modules on Attitude using ASCI and CLASS-Chem

Hard copies of student's responses for ASCI items were transcribed to an excel spreadsheet and analyzed using the scoring template designed by Bauer[6]. When entering students' responses in an excel spreadsheet, no items were left blank. In case where a student had provided same response for all items, the spurious data was not included in the analysis of ASCI. *The p value* and effect size between pre and post ASCI scales were calculated.

For the analysis of CLASS-Chem data, students responses for CLASS-Chem pre and post items were organized in an excel spreadsheet and analyzed as per the CLASS-Chem analysis template [7, 10]. Individual responses were averaged to determine the "overall percentage favorable" for all participants. The "overall favorable percentage" score was measured in terms of statements to which the students answered in the favorable senses, agreeing with the expert response.

7.3.4.4. CRCE Modules on Motivation and Self-regulation

SALES Survey was analyzed quantitatively for the 4 categories: Learning Goal Orientation (LGO), Task Value (TV), Self-efficacy (SE), and Self-regulation (SR). Among the 158 students, a total of 68 responses were obtained for completion of both pre and post SALES surveys. Categories mean and standard deviation values were calculated and the mean scores for each of the four SALES categories were compared using paired sample t-test. Also, the cumulative score for individual categories was calculated and then expressed in three scales.

32 -40- High Motivation and Self-Regulation

25-31 - Acceptable Motivation and Self-Regulation

≤ 24 - Requires improvement on motivation and Self-Regulation

7.3.4.5. Investigating Students Experience with CRCE Modules

To understand how the modules were contributing to student understanding of chemistry, data from the CRE survey was used for this analysis. CRE survey also wanted to understand student perception of modules based on their own experience with integrated modules. After these data were taken, the percentage of student's response to each scale (1-strongly disagree, 2- disagree, 3-neutral, 4-agree, and 5- strongly agree) for each item was analyzed. A total of 103 responses were obtained from students who completed post CRE survey.

Aside understanding how the modules were contributing to student understanding of chemistry, student's ability to transfer and incorporate their newly acquired scientific knowledge from modules was investigated through a semi-structured interview. Data on interviews were collected via zoom. Students' responses to each interview question were coding to identify code frequency. Overall, 20 students were purposely selected for the interview, and each interview took approximately 30 minutes.

7.4. Results and Discussion on CRCE Integration

Findings associated with each aspect of research question are presented in the following sections.

7.4.1. Impact of module integration on academic performance

The impact of the CRCE modules on student academic performance in chemistry was examined using the quantitative data collected from the pre and post MOSART, CAST, CRCE module quizzes, cumulative CRCE module quiz and Cumulative online final exam for the course. At the beginning of study, a pre quiz covering all modules was given to consent students before students took individual module quiz (quiz 1-5). At the end, a comprehensive quiz was given. Analysis on quiz scores show an increase in mean scores from pre the quiz (mean =45.42, S.D.=12.54) to the comprehensive quiz (mean=83.98, S.D.=11.28) which covered all the modules**.** Between these two quizzes, a large effect size of 2.84 was witnessed. Statistically, a significance was set at 0.05 and *p value* less than 0.00001 was reported. This result showing an increase in students' performance in quizzes on modules. The results are presented in **Table 7.2**.

Table 7.2. Descriptive analysis on students' performance in quizzes.

Statistical Analyses	**Pre-Quiz (N=112)**	**Comprehensive Quiz (N=112)**	**Quiz 1 (N=134)**	**Quiz 2 (N=113)**	**Quiz 3 (N=100)**	**Quiz 4 (N=93)**	**Quiz 5 (N=89)**
Mean	45.42	83.98	76.19	83.52	71.10	90.32	89.32
S.D.	12.54	11.28	13.12	10.68	20.49	14.99	15.36
Effect Size	2.84						
t-test	27.85						
p-value	<0.00001						

Students' performance on CAST and MOSART standard tests from the pre to the post show an increase in mean scores from 54.00 to 63.18 for MOSART and 56.44 to 76.13 for CAST. Significance was set at 0.05 and p values less than 0.00001 was reported for both tests. Also, an effect size calculation using Cohen's d indicated large effect sizes of 0.53 and 0.67 between pre and post MOSART and CAST tests. Results on students' performance in MOSART and CAST are presented in **Table 7.3**.

Table 7.3. Descriptive analysis on students' performance in standard tests.

Analyses	Exam 1(%)		Exam 2(%)		Exam 3 (%)		Exam 4 (%)		Final Exam (%)	
	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent	[1]Consent	[2]Non-consent
Mean	76.35	69.75	76.34	73.25	78.90	74.60	76.87	72.26	81.90	57.76
S.D.	13.84	15.46	13.85	18.32	15.13	25.00	17.32	28.0	12.21	39.43
Effect Size	0.46		0.19		0.21		0.27		0.83	
t-Test	2.42		1.29		1.48		1.40		6.59	
df	194		198		198		198		198	
Observed p-value	0.016		0.19		0.14		0.16		< 0.0001	
Corrected p-value	0.01									

Apart from using quizzes, MOSART, and CAST to assess integrated modules on students' academic performance, further analysis was done to investigate the difference between exam scores for the consent group and non-consent group. Students' performance in exam 1-4 and final exam were analyzed. All five exams were taken by both groups at the same time, and in the same manner. The total number of students for the consent group who took the exams was 144, and that of the non-consent group was 56. Two students from the non-consent group did not take the exam 1. This reduced the number to 54 as total sample who took exam 1. Descriptive and inferential analyses on students' performance in exam scores are presented in **Table 7.4.**

Table 7.4. Descriptive and Inferential Analyses on students' performance in exams.

Statistical Analyses	**MOSART (N=96)**		**CAST (N=85)**	
	Pre-	Post-	Pre-	Post-
Mean	54.00	63.18	53.80	69.30
S.D.	15.14	19.34	22.40	23.40
Effect Size	0.53		0.68	
t-Test	5.24		-4.40	
P-value	<0.00001		<0.00001	
df	95		84	

[1]N=144 and [2]N=56 except Exam 1 where [2]N=52

A comparison for the difference in the performance of consent and non-consent students enrolled in the spring semester course showed an increment in students mean percentage scores across the entire exams (exam 1-4 and final exam). Statistically, no significant difference existed between the percentage scores of consent group and non-consent group on exam 2 $p -$ value $= 0.19, \alpha = 0.005, t\ value = 1.29, df = 198$), exam 3 $p -$ value $= 0.14, \alpha = 0.005, t\ value = 1.48, df = 198$), and exam 4 $p -$ value $= 0.16, \alpha = 0.005, t\ value = 1.40, df = 198$.

These analyses showed that though the consent students overall average percentage scores after integration of modules were higher, the effect size between the percentage scores for exams 2, 3, and 4 for consent and non-consent group was small. Also, a moderate effect size of 0.46 existed 0.83 was witnessed between the percentage scores on exam 1 and final exams. Since the integration stage made CRCE modules part of the syllabus component, both consent and non-consent groups benefitted from the modules. This attributes to small effect size between mean scores.

The modules were covered in depth in lecture for particular concepts before later on transitioning to online due to COVID 19, hence impacting students' academic performance.

Large effect size (0.83) with significant difference in final exams may be connected to the fact that the comprehensive CRCE module test (questions from modules) was administered before students took the final exams. Though there was a change in instruction in the middle of the semester, consent students overall average percentage scores in the final online exams was very high. In the middle of the semester, all course materials with integrated CRCE modules were not taught to student's face-to-face. Course moved to online due to the temporary shutdown.

Results from integration of CRCE modules showed an increase in students overall percentage scores in quizzes, and standard tests. These results agree with the results obtained during implementation of CRCE modules. For exams scores in the integration stage, students' performance 2, 3 and 4 were not statistically significant. Despite, a change in instruction in the middle of the spring semester, students' overall percentage scores in exams were very encouraging.

7.4.2. Impact of CRCE Integration on Student Conceptual Understanding

To address research question on student conceptual understanding during the integration of CRCE modules, 72 students' discussion posts for D2L discussion prompts were coded. The same coding scheme used during the piloting stage and implementation stage was adopted. For inter-rater reliability, 2 graduate students were asked to independently code all posts. Evaluation consistency among the codes was 83%. Subcategories were further used to characterize students answers to discussion prompts. Explanation of each code used for evaluating student discussion posts is as follows:

Conceptual understanding includes – scientifically correct explanation and definition of concept in detail along with examples that are coherent and consistent.

Conceptual mismatch or gap means that students are not able to correctly tie the concept or explain it in words and they mismatch the example with the concept, or their explanation lacks details along with example. There is an apparent inconsistency in student response as compared to the scientifically correct conceptual explanation. Some coherence in statement of concept and example.

Incorrect understanding/poor conceptual knowledge There is essentially a complete lack of understanding in response in discussion and student is not showing any coherence between statement of concept and example.

Relevance of chemistry/ concepts to student as evidence in either in context of:

a) **Personal application (R-PER):** Student provides examples in response to discussion prompts that are more personal in nature for example – brushing teeth or walking to class or things done in and around home.

b) **Professional application (R-PRO)**: student provides examples in response to discussion prompts that are more professional oriented for example job, career, or work settings.

c) Impact on life (I-OL): Student sees big picture and provides examples in discussion in terms of how the chemistry impacts environment, life, human body, sustainability, industry, a certain field etc.

In module 1, majority of students after explaining concept of matter and measurement expressed the importance of concepts in everyday activities. Students were able to discuss how these concepts contribute to the big picture with respect to the application of chemistry. Code frequency for correctly explained with provided detail examples for module 1 was 608. An example of conceptual understanding is.

One example of ancestors using scientific method would be Charles Darwin's theory about natural selection and that all species arise develop variation that help them compete and survive in their environment. He used the scientific method by observing birds on different islands that looked similar so he stated a hypothesis that animals will breed with other animals who have a desirable trait that will increase their chance of survival (natural selection) while animals who don't have a desirable trait will not pass on their genes. He then observed how breeders crossbred animals to produce different varieties and made the conclusion that animals in the wild must do the same thing. One example would be when I am making my Mac & Cheese in the dorm room. I need to measure 1 cup of water to put in a bowl with the macaroni. Another example would be measuring how much detergent to put in with my clothes depending on how big of a load. We apply the concept of density when we swim since our density keeps us afloat. Another time when we apply the concept would be filling balloons with helium, so they raise since helium has a low density.

We come across every state of matter in our surrounding. The air and oxygen we breathe in is a gas, every building we walk by is matter out of solid matter, and the water we drink or when it rains is in the liquid state. The module has helped me understand that Native Americans used the scientific method in everyday life to figure out things like what *plants are harmful and what ones can be used as medicine for the sick. They would find a plant and experiment with it to see what effects it had on someone's body. We do the same thing today when we are experimenting with new drugs, except that we do it in a more controlled environment to get more accurate results.*

Apart from most students correctly explaining matter and measurement, students gave examples to show how the concept is applicable to their lives, some students mismatched some example of application of matter and measurement. Frequency of students' discussion posts that were coded as conceptual knowledge mismatch is shown in **Table 7.5**. An example of conceptual understanding mismatch is.

An example of using the scientific method in everyday life could be waking up and observing that my laptop is dead. I could create the hypothesis that my laptop is out of battery. I would then plug in my laptop to get it to work again. The scientific method should always be done in order, but sometimes not all steps will be used.

Table 7.5. Frequency of Codes and Summary Data (Matter and Measurements) for spring 2020.

Code	Color Coding Scheme	Code Frequency-Module 1	Total Code Score
CU	Green	608	1216
CM-G	Orange	214	214
IC-U	Red	54	0
R-PER	Brown	434	434
R-PRO	Blue	47	47
I-OL	Yellow	105	105

A higher recorded code frequency for conceptual understanding explains how students showed a deeper conceptual understanding on matter and measurements. Also, the number of times students provided examples that were professionally and personally applicable were 47 and 434. Example of students' quotes are presented in **Table 7.6**

Table 7.6. Module 1 summary of codes and representative quotations for student discussion data (Spring 2020).

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	One example where our ancestors applied the scientific method is by hunting. When they hunted buffalo, the native Americans had to test what weapons and way of killing would work best to kill buffalo. They could have compared hunting on barefoot versus on horseback. With weapons they were able to test what worked better, a bow and arrow or a spear, to kill a buffalo. Native Americans also had learned how to be efficient with killing a greater number of buffalo at once by stampeding them off a cliff. Cooking, more specifically making homemade salsa, is a time where scientific method is used often. Observation is used to help determine what kind of salsas you like in taste, smell, and texture. A hypothesis is made by thinking if you add a certain ingredient, then it will add an extra kick of spice. Experimenting is making the salsa with that extra ingredient. Your conclusion will determine if you will keep that ingredient in there or report and record that you will not use that ingredient for the next time you make salsa. The scientific method does not always have to be in order. Repeating or mixing up the steps can occur before you make your final conclusion, as it can help with whatever you are testing, to fit the	The scientific method has been around longer than I realized. Back before North America was colonized, Native Americans used the scientific method when figuring out what was edible and what was not. They observed other animals and paid attention to what they were eating to help them decide what might be edible. Fortunately, I do not have to use the method in this way. However, I do use certain pieces of it like hypothesizing what my roommates and I would mutually enjoy for food, based on what I have seen them eat. I then test the hypothesis with an experiment by cooking a new dish and letting them try it. In this example, I am only using a few of the step in the scientific method, because some of the steps are not necessary for certain situations. This shows that you do not always need to use this method in a sequential order. It is also interesting to note that I use measurements in my everyday life. For example, when I measure out a different amount of ingredients for something I am making. Density is another thing that plays a role in everyday life. For example, if someone who has a high BMI goes to the pool, they may be able to float in the pool better than someone with a low

	need or capability you have for that test.	BMI, because fat is less dense than water. This module has helped show me the relationship between modern day science and the Native Americans who lived in North America long ago. For example, they used certain parts of the scientific method when figuring out what was edible in the wildness and what was not by observing other animals' diets and testing their hypothesis by eating some of those same things.
Conceptual mismatch or gap (CM-G)	One area that I use the scientific method is when I walk to my classes from my dorm. When it is cold outside, everybody wants to take the shortest route to their class to stay out of the cold. By looking at the weather, I can observe what the weather is like outside. I then can choose a way that I think is best, which is forming the hypothesis. I then perform the hypothesis by walking outside to my class. I then conclude if it was the best way by how cold I am when I get to my class. If I am freezing cold, I find a different way to go back to my dorm. If I am not too cold (since its impossible not to be cold in South Dakota), I take the same way back to my dorm. The next time I must walk to that class, I remember which way I took before that I was not too cold and take that way to class.	The scientific method is not always used in the same order. Some days you might skip the experiment step and come right to a conclusion or might not have a question and just experiment. It all depends on your needs.
Incorrect understanding/poor conceptual knowledge (I-CU)	I think we use the Scientific Method a lot more than we are aware of. Do you ever put ice in your water? Ice is a perfect example of density because it sinks to the bottom of your cup. (because ice is denser than water).	I think you can apply the concept of density to life by arranging a house or room. You must know how much space furniture is going to take up and how much space you have in your room.

	Using measurements is a every happening, sometimes you just do not realize that you are using them. Density in everyday life could be the use of measuring how many apples you need in apply pie. You can take the apples and full a glass to see how many you need for the recipe	
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	My ancestors used the scientific method to test which land they should settle on and farm. They most likely tested which land was fertile and could produce abundant crops. An example of using would the scientific method in my everyday life would be choosing faster routes to get home. I can observe that my friends get home faster, then I can ask why I am not getting home that fast. Next, I can form a hypothesis that they are taking a faster route. Then I can predict that I will get home just as fast if I take the same route. Finally, I can test my hypothesis. A person can change the order of the scientific method based of need. Like if they want to go back an reevaluate and make a new hypothesis.	I use measurements every day. I start my day by measuring 8 ounces of water to make my coffee. I also count my calories throughout the day. I apply the concept of density in practical ways by seeing which kinds of pop float in cooler or in the lake during the summer. The states of matter that I come in contact with are solids, liquids, and gases. Solids are like my desk, computer, and a penny. Liquids are like water, pop, and coffee. Gases are like oxygen, Carbon dioxide, and nitrogen in the air. The module has helped me understand that people were using science well before others even thought of it as a practice
Professional application (R-PRO)	In this module, I thought it was interesting how they made a measurement system based on common things like body parts. When they broke down the different plants and substances the Natives used to use, that helped paint a mental picture of how important chemistry is in everyday life. I used	I have used scientific methods several times in my life without even knowing it. While I worked as a plumber you could be faced with several different problems but over time by "trial and error" attempt to find the most efficient and correct fix for the problems you encountered. I would write

	to work for an electrical company and when we were stripping the insulation off the wire to terminate the wire, we would use the width of all four fingers to determine where to cut the insulation. You had to strip 4-5 inches of insulation off, so using our hands we knew that it would be ~four inches. So, it just goes to show the resourcefulness of humans, and that some methods of measuring or conducting scientific experiments are simply timeless.	down observations of what symptoms I encountered on a job, then I would write the steps I took to resolve the problem in order. After the job was done, I would reflect on the steps I took and develop questions like, "could I have done this a different way to have a better and more efficient outcome?" This led me to become far more proficient and confident in diagnosing and problem solving. These theories or efficient ways of fixing a problem become standard operating procedure for the next job.
Impact on life (IOL)	This module has helped me realize that parts of our everyday life was discovered by the Native Americans many years ago. Things like feet when measuring something were discovered by the Native Americans many years ago. They created the measurement and we have changed it a little bit to make it more accurate. This has also helped me relate them to us. They would go about their life a little different but in ways the same. One last device that has helped farmers now days is the chinampas by helping farmers grow crops. Great everyday examples to use to show the different states of matter, a big one being the emissions from cars because that tends to be brought up quite a bit as a threat to our ecosystem.	It is very interesting to see how much of our life is circled by measurements. In almost every conversation, measurements are a part of it. Asking where you are from or how far you live from the grocery are all measurements as well. The module has taught us that people were using science long before anyone thought of it like that. I certainly never thought of things like perfume and medicines as involving chemistry.

Module 2 during the integration stage was focused on the concept of chemical bonding. Analysis of students' discussion posts in response to the discussion prompts on chemical bonding module showed that students were able to conceptually explain what chemical bonding is, and the types of chemical bonding with examples. Students were able to explain ionic and covalent bonding in details, and provided examples of compounds that undergo ionic and covalent bonding. From students' discussion posts, the frequency of the code relating to scientifically correct explanation of chemical bonding was 107 (**Table 7.7**).

Table 7.7. Frequency of Codes and Summary Data (Chemical Bonding).

Code	Color Coding Scheme	Code Frequency-Module 2	Total Code Score
CU	Green	107	214
CM-G	Orange	28	28
IC-U	Red	8	0
R-PER	Brown	28	28
R-PRO	Blue	0	0
I-OL	Yellow	69	69

Example of conceptual understanding would be;

An Ionic compound is a compound that is held together by a cation and an anion. This works like magnets; the negative side attracts to the positive side and repels the negative side. The anion gives up its extra electron to the cation, who need one to get a full octave.

The frequency of the code not related to conceptual explanation or in words and they mismatch the example with the concept were 28. Example of conceptual mismatch or gap based on student post is;

Ionic Compounds that contain any hydrogen atoms are labeled as acids. When the ion is a bas, it consists of hydroxide. For the ion to become a salt, the ion must become neutral or without a charge

Students showed transfer of knowledge from ionic bonds, covalent, and trends of the periodic table into the real-world scenarios and explained its impact on life (I-OL code frequency = 69). Instances where students related the understanding of concept of ionic bonding and covalent bonding to their everyday applications were 28. More of students' quotes on module 2 prompts can be found in **Table 7.8.**

Table 7.8. Module 2 summary of codes and representative quotations for student discussion data (Spring 2020).

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	An ionic compound is a chemical compound made up of ions and held together by electrostatic forces. An example of this is the ions of Sodium and Chloride. Together each uses the opposite charge of the other ion to stick together to form a salt. The charges must balance out for it to be an ionic compound.	My understanding of Ionic compounds is that they will completely give away electrons just to completely fill the octet. You can use the periodic table by looking at the noble gases and how many would give to gain or lose to get the full octet.
Conceptual mismatch or gap (CM-G)	A salt results when an acid reacts with a base. Both are neutralized. Many acids only show acidic properties when water is present.	Many acids only show acidic properties when water is present.
Incorrect understanding/poor conceptual knowledge (I-CU)	A situation that my own family applied ionic bonding to was when my own maternal and paternal grandmothers died but overcame the negative situation by communicating all the positive memories that were made. An example of something that was done within our own household was when we had to adapt our house to today's technology to	Compounds containing oxide or hydroxide are classified as a base. An example of a base would be Ammonium hydroxide. During salt formation, ionic compounds balance with the opposite charge and form a neutral compound.

	accommodate for everyday life.	
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	We use ionic bonding in our everyday life through our usage of baking soda. More specifically, cooking with baking soda. Baking soda creates carbon dioxide when it is mixed because it reacts when the baking soda is mixed with a liquid and an acidic ingredient.	Sodium Chloride is table salt, which most people use every day. You also use sodium chloride to deice roads and sidewalks. Some people also use Calcium Chloride to deice stuff, but it does more harm to the concrete, so most people use sodium chloride, even though the Calcium Chloride melts ice better
Professional application (R-PRO)	NA	NA
Impact on life (IOL)	For Native Americans, salt was a necessity to livelihood. Salt allowed for the preservation of foods that they obtained. This was key for transporting the food. They also consumed iodine through kelp to help with preventing disease.	The sodium atom in this compound loses an electron to become Na+, while the chlorine atom gains an electron to become Cl-. The native Americans used salt to keep their meat good and healthy. Without salt for their meat, they would not be able to save any of their wild game.

Students' discussion posts on concept of chemical bonding show how these students have a depth understanding of concepts of chemical bonding. Students also in their discussions show how they connect the concept in the classroom to outside of the classroom.

Also, **Module 3 focused on** the concept of chemical reactions. Analysis of students' discussion posts in response to the discussion prompts to this module showed that students were able to conceptually explain the types of chemcial reactions, and gaves examples of the types of chemical reaction. Frequency of each code from discussion posts is shown in **Table 7.9.**

Table 7.9. Frequency of Codes and Summary Data (Chemical Reaction).

Code	Color Coding Scheme	Code Frequency-Module 3	Total Code Score
CU	Green	146	292
CM-G	Orange	21	21
IC-U	Red	3	0
R-PER	Brown	19	19
R-PRO	Blue	1	1
I-OL	Yellow	87	87

From the students' discussion posts, the code frequency for scientifcally correct explanation of chemical reactions was 146. Examples of conceptual understanding would be;

There are eight types of chemical reactions. The chemical reactions are Oxidation (reduction or redox), Direct combination or synthesis reaction, Chemical decomposition or analysis reaction, single displacement or substitution reaction, metathesis or double displacement reaction, acid-base reaction, combustion, isomerization.

In the oxidation reactions redox reactions may transfer elections between chemicals and the oxidation numbers in the atoms are changed.

Examples of conceptual mismatch or gap based on students' posts is;

Neutralization Chemical Reactions -When an acid and base react together and form water.

Precipitation Reaction-When there is a reaction that causes a solid to be byproduct.

Overall, there were 87 instances in student discussion wherein students discussed the relevance of chemical reactions in terms of big picture of viewing reactions as highly applicable to a discipline of life in general.

Frequency of code relating to students incorrectly explaining the concept of chemical reactions in words was 3. Examples of students' quotes are presented in **Table 7.10.**

Table 7.10. Module 3 summary of codes and representative quotations for student discussion data (Spring 2020).

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	The combination reaction. In this reaction, two or more substances combine to form a new one. Next, a compound breaks down into simpler substances in a decomposition reaction. In a single-replacement reaction, one element replaces another. A double replacement reaction takes place when two elements switch places. Finally, in a combustion reaction, a substance reacts with Oxygen gas, releasing light and heat.	There are five main chemical reactions, Synthesis, Decomposition, Single replacement, Double replacement, and Combustion. Synthesis is like A+B=AB. Decomposition is like AB=A+B. Single replacement is like A+BC=C+BA. Double replacement is like AB+CD=AD+CB. Combustion is a trickier one because it adds oxygen to the product side.
Conceptual mismatch or gap (CM-G)	While nuclear reactions also may produce new matter, nearly all the substances you encounter in daily life are the result of chemical changes	While nuclear reactions also may produce new matter, nearly all the substances you encounter in daily life are the result of chemical changes
Incorrect understanding/poor conceptual knowledge (I-CU)	I know one way the equilibrium works is when I run on the treadmill it works. As fast as you run forward the treadmill is moving you backwards. You are in	I know one way the equilibrium works is when I run on the treadmill it works. As fast as you run forward the treadmill is moving you backwards. You are in

	equilibrium with the treadmill. pretty neat I think.	equilibrium with the treadmill. pretty neat I think.
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	My family uses the slash and burn methods with our CRP fields which help with growth and benefits the environment. Chemical reactions happen every day, all the time and we need them to happen to live	I use chemical reaction when i hard boil an egg. Drinking a fizzy cool drink is chemical equilibrium and the metabolism of food in the body is energy rates. This module has opened my eyes to understand not just only the different types of reactions but how what we do in our everyday life is related to it
Professional application (R-PRO)	I come from a long line of farmers and ranchers. In modern times, farmers and ranchers depend on chemical reactions everyday just to do their job. Where would farmers be without their tractors with the high demand for food across the globe? However, when my ancestors were first farming in the Ukraine and then in South Dakota, tractors were not available. In turn, they relied on horses, plows, and other simpler tools to get the job done.	NA
Impact on life (IOL)	Native Americans applied the concept of chemical reactions, energy, reaction rates and chemical equilibrium when they created fire, they needed to know that there was a combustion reaction and how long that reaction would take place, as well as the energy needed to keep the reaction going	A big thing Natives used was freezing food by using sublimation. This allowed them to store food longer

On module 4, students' discussion posts in response to the discussion prompts on concept of solutions show how students were able to conceptually explain what solution is, and the intermolecular forces that affect the solubility of a substance. In students' discussion posts, the code frequency for scientifically correct explanation of concept of solutions was 107. Frequency of each code from discussion posts is shown in **Table 7.11.**

Table 7.11. Frequency of Codes and Summary Data (Solutions).

Code	Color Coding Scheme	Code Frequency-Module 4	Total Code Score
CU	Green	107	214
CM-G	Orange	9	9
IC-U	Red	0	0
R-PER	Brown	29	29
R-PRO	Blue	15	15
I-OL	Yellow	76	76

Students gaves examples of the phases of solutions. Example of quote showing conceptual understanding would be;

Inter molecular forces aid in solubility by powering the "like dissolves like" idea. the stronger the forces between molecules, the stronger the solubility of the solute within the solvent. Entropy helps solubility where the more endothermic the enthalpy a solution is, the less soluble the compound will become.

Example of conceptual mismatch or gap based on student post is;

Another solution would be steel. Steel is made up of iron which comes from iron ore and carbon from coal.

Students also made connection between the ideas in concept of solutions to their everyday applications and to their professional applications (Code frequencies for personal applications and professional applications are 29 and 15). **Table 7.12.** presents summary data, and examples of quotes from module 4 during the integration stage of CRCE modules.

Table 7.12. Module 4 summary of codes and representative quotations for student discussion data (Spring 2020).

Code	Representative Quotation 1	Representative Quotation 2
Conceptual Understanding (CU)	It is important to understand how solutions work because we do not want to combine the wrong substances to create something dangerous. For example, we don't want to combine bleach and ammonia when cleaning because it can form a toxic gas. My understanding is that like dissolves like. For example, nonpolar solvents dissolve nonpolar solutes.	An example of a Solid liquid is Saline which is saltwater. An example of gas and liquid is the soda pop Coca Cola. Solid-solid is steel. Steel is made of carbon and iron. An example of gas-gas is neon light which is cool. And finally, an example of liquid-liquid is 70% isopropyl alcohol.
Conceptual mismatch or gap (CM-G)	A solution is a liquid that has a solute that is equally distributed within a solvent	A solution is a homogenous mixture with particles that are about the size of ions or small molecules
Incorrect understanding/poor conceptual knowledge (I-CU)	NA	NA
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	My ancestors used many solutions, salt water being a main one, especially when it comes to meat. Salt can dry meats out but also add in flavor all while preserving the meat. Therefore, before the meat was cooked it would sit in a saltwater bath to help tenderize it and add flavor.	In my everyday life I use different types of solutions. In the house I will use solutions to clean such as adding dish soap to water or bleach to water. In farming, solutions are used to fertilize fields etc.

Professional application (R-PRO)	As an agronomist, knowing about solutions will be important to my career because I will have to work with chemicals firsthand and how they would react with what is already in the soil.	As I grew up on a cow-calf operation and plan to return, mixing replacement colostrum for newborn calves takes the ability to dissolve to create a solution to help boost a newborn calves 1st few hours. If there were products that would not dissolve in my milk powder, it would not go down the calf's throat well
Impact on life (IOL)	The Native Americans applicated the concept of solutions for many things, including turning achiote into dye and flavorings through maceration and Allspice, which is a season with flavor resembling a blend of pepper, cinnamon, juniper, and cloves.	Native Americans used the concepts we have learned in a number of ways, one being how they made Adobe by mixing the clay from the ground and water to build a number of things, such as bricks to make their homes.

From discussion posts on Module 5, students' discussion posts in response to the discussion prompts on acids and bases show how students were able to explain in details what acids and bases are through examples, classifications of acids and bases as organic or inorganic, and the industrial and tradition applications of acids and bases. The code frequency for scientifically correct explanation of acids and bases was 65. **Table 7.13** displays the frequencies of codes from students' discussion posts.

Table 7.13. Frequency of Codes and Summary Data (Acids and Bases).

Code	Color Coding Scheme	Code Frequency Module 5	Total Code Score
CU	Green	65	130
CM-G	Orange	10	10
IC-U	Red	5	0
R-PER	Brown	39	39
R-PRO	Blue	3	3
I-OL	Yellow	71	71

Example showing students conceptual understanding of acids and bases would is

Lactic acid fermentation is a metabolic process by which glucose and other six-carbon sugars (also, disaccharides of six-carbon sugars, e.g. sucrose or lactose) are converted into cellular energy and the metabolite lactate, which is lactic acid in solution.

Also, examples of conceptual mismatch or gap based on student post is;

Water is the suggested solution for Nitrous oxide because it can dissolve in alkaline solution of sulfate.

From the discussion posts, it was found that along with explaining the terminologies, students were able to also explain how acids and bases are applied in their everyday and envrionmental activities. The number of times students referred to their personal application of the concepts of acids and bases was 39. Students also discussed the relevance of the concept of acids and bases to lives. **In module 5**, there were 27 instances in students' discussion posts where students included references to how they apply the ideas presented in CRCE modules in their everyday activities. **Table 7.14 show a** summary data, and examples of quotes from module 5.

Table 7.14. Module 5 summary of codes and representative quotations for student discussion data (Spring 2020).

Code	**Representative Quotation 1**	**Representative Quotation 2**
Conceptual Understanding (CU)	Given reaction is an acid base reaction that means neutralization reaction where these react with each other to form a metal salt and water. The only solution to these problems of acid rains is by ensuring use of renewable sources of energy and lesser fossil fuel burning for energy production.	Lactic acid has been used to ferment and culture foods for centuries. Citric acid was a big disinfectant used to fight off bacteria. Milk of magnesia used to be made into soaps and detergents. These are all things that the indigenous Native-Americans could of use to their advantage.
Conceptual mismatch or gap (CM-G)	some of the suggested problems would be is that oxygen is a huge react when acid or bases react with oxygen will cause metal to rust and when comes in contact with water there is oxygen in the water also making it dangerous in the water also	The acids had a lack of oxygen while the bases did have oxygen, along with the different properties each have.
Incorrect understanding/poor conceptual knowledge (I-CU)	Depression, anxiety, moodiness, and lung and heart diseases can be a result of acids and bases that are not balanced.	A possible solution is finding a base that neutralizes the acid rain and add that to the aquatic systems to prevent damage. Also, for surface protection you can coat surfaces with a finish that is basic and will not decay
Relevance of chemistry/ concepts to student as evidence in either in context of		
Personal application (R-PER)	My ancestors use acids and bases when it came to baking, cooking, cleaning, or preserving. My great grandmother used vinegar in all her home remedies. Also, my grandmother used to pickle hearing, cabbage, pig feet's, and asparagus.	Today I use acids and bases for many things, I use toothpaste, bleach, limewater, and cleaning products.

Professional application (R-PRO)	Citric acid is used in the food and beverage industry for various purposes as pharmaceuticals and for other industrial uses. It is an organic carboxylic acid and can be extracted from the juice of citrus fruits by adding calcium oxide to form calcium citrate.	It is used in the food and beverage industry for various purposes as pharmaceuticals and for other industrial uses.
Impact on life (IOL)	Native Americans used acids and bases to make soaps and mix with their corn to make peel the hard coating off and make it easier to grind	By limiting the amount of waste in our communities, we can contribute to the decline of the acid rain production. Our garbage ends up in fields and drainage ditches that sometimes evaporate in the air. Recycling will keep our environment cleaner thus reducing production

Overall, the discussion of CRCE modules demonstrated students deep transfer of knowledge by connecting concepts to the real-world applications. Students were able to provide scenarios either from their everyday activities, showing students interest and appreciation to the modules. This pedagogical approach applied during the integration together with results from implementation stage truly show how CRCE modules enhance students conceptual understanding. Analyses also revealed student’s collaboration, therefore promoting positive attitude and confidence about the course and with other students. Again, it is important to note that the discussion prompts were mainly guidelines and that the students were not required to respond to every prompt.

7.4.3. Impact on Students' Attitudes toward Chemistry

7.4.3.1. ACSI Survey Results

Impact of integrated modules on students' attitude toward chemistry (ASCI) was evaluated using several statistical analyses. Paired sample t-test with $\alpha = 0.005$ was performed to evaluate separately the impact of integration of modules on students' attitudes toward chemistry (**Table 7.15**).

Table 7.15. Attitude Scores for students Enrolled in Spring 2020 semester Chemistry 106 (N=59).

Subscale	**Pretest Scores**		**Posttest Scores %**		**p-values**	**Effect Size**
Factors	Mean	% scores	Mean	% scores		
Interest and Utility	4	51	4	55	0.5	0.09
Anxiety	5	60	5	69	0.5	0.11
Intellectual Accessibility	3	30	3	29	0.12	0.31
Items						
Fear	5	60	4	52	0.23	0.17
Emotional Satisfaction	3	36	3	31	0.66	0.06

During the Spring semester, 59 student's emotional satisfaction as well as intellectual accessibility for chemistry decreased (*p value* =0.66, Cohen's d=0.06, p=0.12, d= 0.31, respectively). There was an increase in students' interest and utility though this shift was not significant (p=0.5, d= 0.09).

Moreover, their anxiety also increased but not significant with minimal effect size (p=0.5, d=0.11). Students fear about chemistry decreased but not significant at the end of the semester (*p value*=0.23, d=0.17).

However, students showing an increase in interest and utility and decrease in the fear for the subject of chemistry contracts from the study conducted during the implementation stage during which the results were (*p value*=0.0000047, d=0.61 for Interest and Utility, and *p value*= < 2.2e-16, d=1.56 for Fear).

A closer look at these results points to the fact that during the fall 2019 semester the instruction was face to face with the implementation of CRCE modules whereas in spring 2020 semester half-way through the semester the instruction was moved to online format. This might have contributed to shift in student attitudes towards the subject of chemistry specifically with respect to increase in anxiety, and emotional satisfaction in general since the integration of CRCE went online during the middle of semester. However, students do show a positive gain in interest and utility and decrease in fear of the subject itself, which seems to be a positive outcome of the CRCE module. It appears that the way the modules are designed, it helps students see chemistry as an important aspect relevant to life (as evidenced by the qualitative student discussion data, student response to CRE survey and qualitative interviews).

7.4.3.2. CLASS-Chem Survey Results

CLASS-Chem survey probes students attitudes and distinguishes the attitudes of experts from novices[7]. Overall %favorable attitudes score is equal to the percentage of statements for which the student's response agrees with that of an expert chemist. The %unfavorable is vice versa, that is a percentage of statements for which the student's response agrees with that of a novice. Subscales also known as categories, relating to student attitudes in CLASS-Chem are personal interest (PI), real world connection (RWC), PS: general (PSG), PS: confidence (PSC), PS: sophistication (S), sensemaking/effort (SM), conceptual connections (CC), conceptual learning(CL), and atomic-molecular perspective of chemistry(AMP). The overall results of the CLASS-chem survey for the general chemistry survey course during integration of CRCE modules are presented below. Complete data was available from 63 students who completed the pre and the post survey. From **Table 7.16**, a strong positive % difference in shift was seen from pre to post CLASS-Chem survey.

Table 7.16. Comparison of general chemistry students' favorable responses for pre- and post-CRCE CLASS-Chem survey on student's attitudes in chemistry.

Survey Response Categories (N=63 student participants)	Favorable Pre-survey Response (%)	Favorable Post-survey Response (%)	Difference in Average Shift (%)	Standard Error in Shift (%)
Overall	39.2	47.6	8.4	1.9
Personal interest	39.1	59.9	20.8	3.7
Real world connection	45.2	56.2	11.0	3.9
PS: general	42.5	53.3	10.8	3.3
PS: confidence	54.4	66.9	12.6	4.7
PS: sophistication	30.7	50.2	19.5	3.4
Sensemaking/effort	45.2	45.2	4.6	3.0
Conceptual connections	32.0	41.4	9.4	3.4
Conceptual learning	27.0	35.6	8.7	3.3
Atomic-molecular perspective of chemistry	45.0	60.3	15.3	4.4

In general, the 63 students % favorable scores for all categories describing attitude show a positive shift. Difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were**,** 20.8%, 11.0%, 10.8%, 12.6%, 19.5%, 4.6%, 9.4%, 8.7%, and 15.3%. From the results, it was seen that the attributes of attitude were impacted by integrated CRCE modules. Also, **Figure 7.1** is a summary of the overall results of the CLASS-chem survey for the general chemistry survey course in Spring 2020.

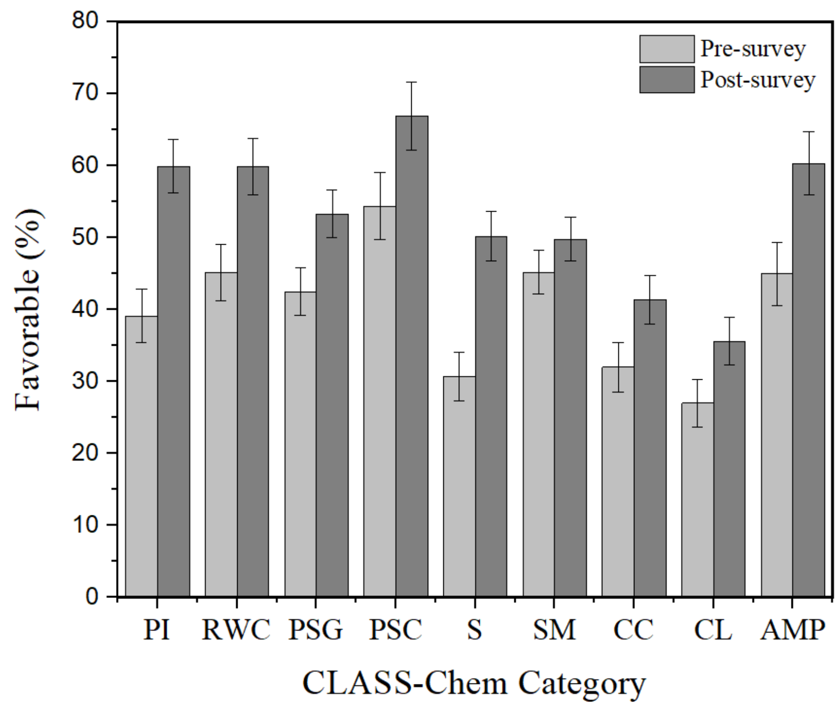

Figure 7.1. CLASS survey "overall" favorable scores for pre and post integration of the CRCE modules.

From **Figure 7.2**, a comparison of %favorable and %unfavorable scores for the Pre and Post CLASS survey for CRCE integration show all the 63 student's responses agreeing with that of an expert chemist.

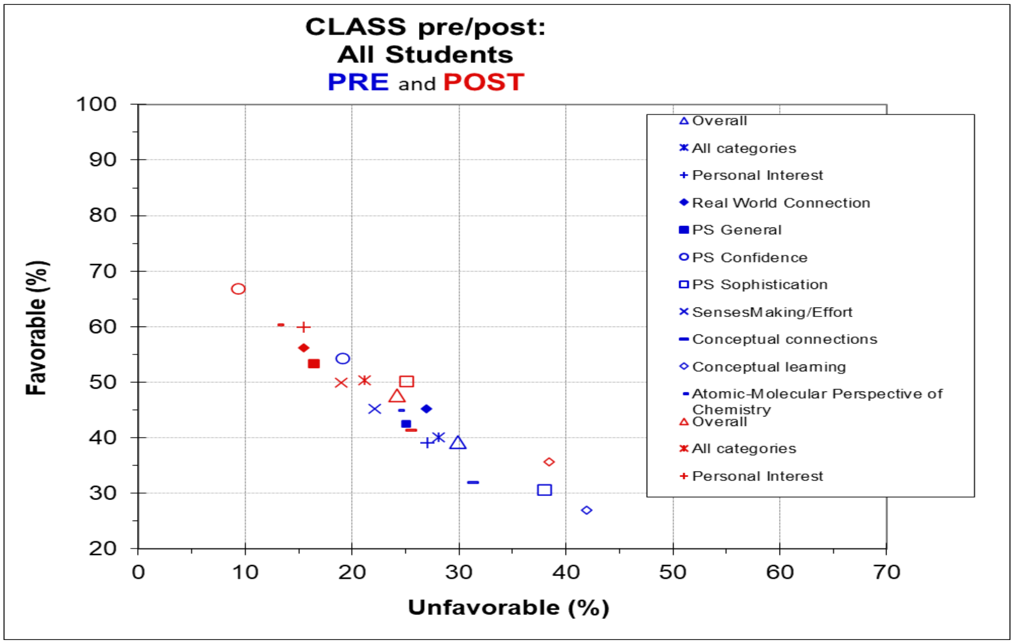

Figure 7.2. Comparison of favorable and unfavorable scores for the Pre and Post CLASS survey for CRCE integration.

Further analysis on attitudes of women (N=32) in the course showed positive shifts for all categories except sensemaking/effort. There was a negative shift for sensemaking category (difference in average shift is (-0.6%). Difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were 18.3%, 5.7%, 2.8%, 6.7%, 18.8%, -0.6%, 3.5%, 8.6, and 11.6%. This result is presented in **Table 7.17.**

Table 7.17. Comparison of general chemistry women favorable responses for pre and post CRCE-CLASS-Chem.

Survey Response Categories N=32 student participants)	**Favorable Pre-survey Response (%)**	**Favorable Post-survey Response (%)**	**Difference in Average Shift (%)**	**Standard Error in Shift (%)**
Overall	42.5	47.6	5.0	2.8
Personal interest	50.0	58.3	18.3	5.5
Real world connection	48.4	55.7	5.7	5.8
PS: general	51.6	51.2	2.8	4.4
PS: confidence	63.0	69.7	6.7	7.9
PS: sophistication	32.1	50.9	18.8	4.5
Sensemaking/effort	51.1	50.6	-0.6	5.0
Conceptual connections	36.1	39.6	3.5	3.9
Conceptual learning	26.9	35.4	8.6	5.0
Atomic-molecular perspective of chemistry	47.3	58.9	11.6	6.3

Figure 7.3 is a summary of the results on attitudes of women in the spring 2020 semester course. Again, this analysis shows positive shifts for all CLASS-Chem categories for assessing attitudes except sensemaking/effort. Women sensemaking/effort showed a negative shift of -0.6%.

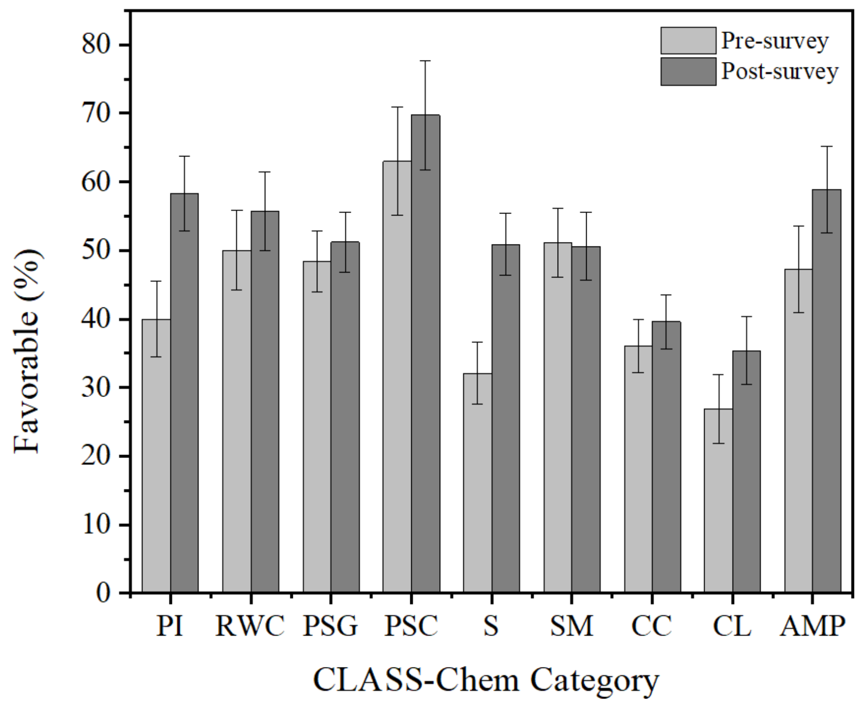

Figure 7.3. CLASS survey women % favorable scores for pre and post.

Also, a comparison of %favorable and %unfavorable women scores for the Pre and Post CLASS survey for CRCE integration show all the 32 women student's responses agreeing with that of an expert chemist except their sense making or effort which did not agree with that of an expert chemist (**Figure 7.4)** integration of the CRCE modules.

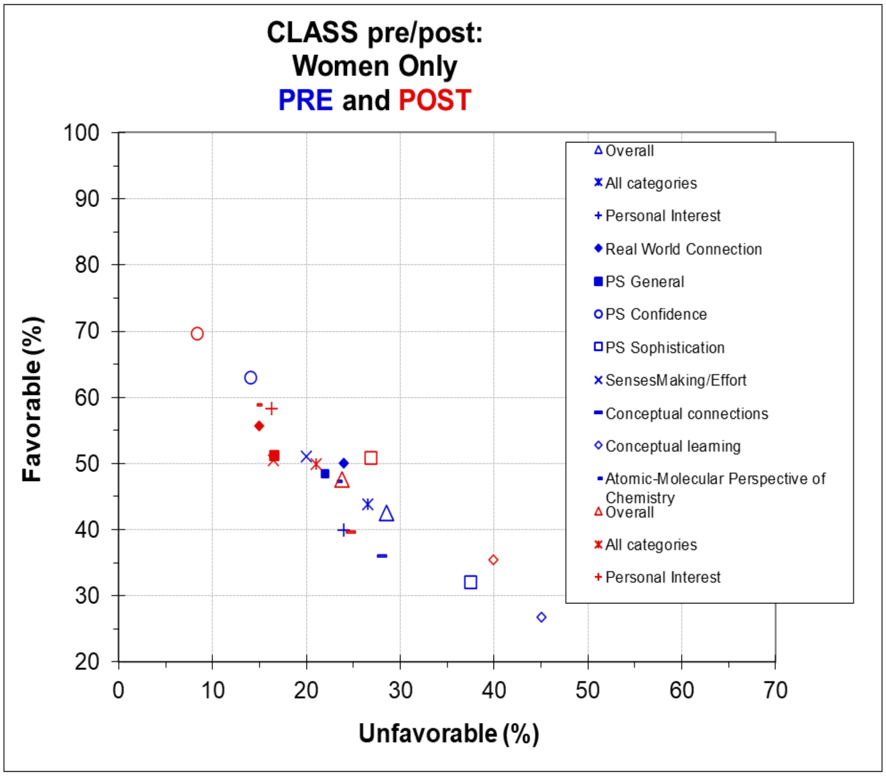

Figure 7.4. Comparison of overall favorable scores at the start (Pre) and end (Post) for women under each category.

Comparing this result from integration of CRCE to the implementation stage of the CRCE modules show similar results (positive shifts) for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry but not sensemaking/effort. Women sensemaking/effort was shifted negatively (-0.6%) during integration of CRCE modules. This results may be attributed to the fact that during the fall 2019 semester the instruction was face to face with the implementation of CRCE modules whereas half-way through the spring 2020 semester, the instruction was moved to online format. This might have contributed to shift in female students' attitudes towards the subject of chemistry as determined.

After assessing the impact of integrated modules on female students' attitudes, the attitudes of male students (N=31) who participated were assessed. From **Table 7.18,** the difference in average shift for personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry were 21.3%, 13.5%, 13.8%, 14.4%, 13.9%, 5.4%, 10.5%, 6.1%, and 16.9%. All 31 students % favorable scores for all categories describing attitude show a positive shift. analysis when compared with that of CRCE implementation stage showed similar results.

Table 7.18. Comparison of general chemistry males' favorable responses for pre and post CRCE-modules.

Survey Response Categories (N=31 participants)	Favorable Pre-survey Response (%)	Favorable Post-survey Response (%)	Difference in Average Shift (%)	Standard Error in Shift (%)
Overall	38.5	48.1	9.6	2.8
Personal interest	40.3	61.5	21.3	6.4
Real world connection	42.3	55.8	13.5	6.4
PS: general	40.4	54.2	13.8	5.1
PS: confidence	49.0	63.5	14.4	6.3
PS: sophistication	34.6	48.5	13.9	5.8
Sensemaking/effort	42.9	48.3	5.4	4.3
Conceptual connections	33.5	44.0	10.5	6.6
Conceptual learning	30.2	36.4	6.1	5.8
Atomic-molecular perspective of chemistry	43.6	60.5	16.9	7.1

Also, **Figure 7.5** is a summary of the results on attitudes of men in the spring 2020 semester course. This result shows positive shifts with respect to attitudes assessment with CLASS-Chem survey during integration of CRCE modules.

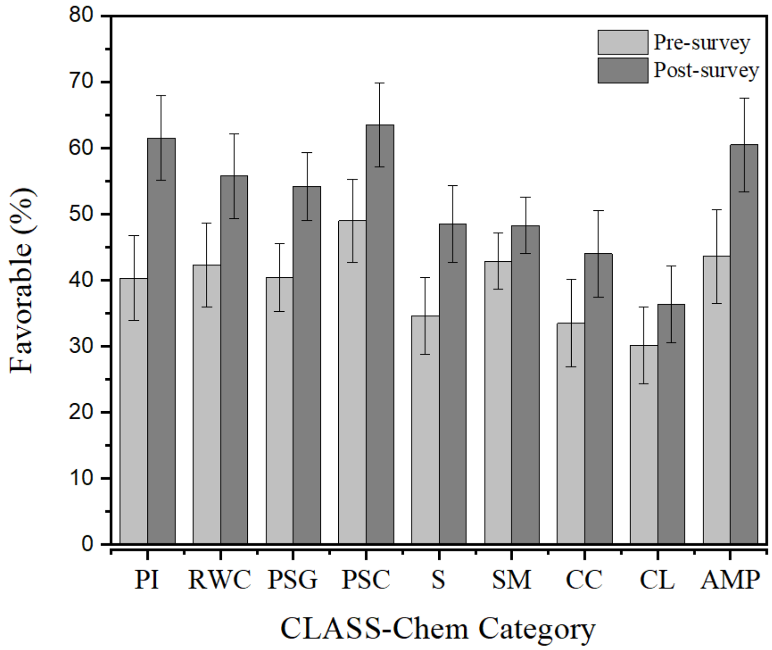

Figure 7.5. CLASS survey men favorable scores for pre and post integration of the CRCE modules.

Also, it was also found that for the male students (N=31) in general chemistry survey course, their attitudes were consistently like that of a chemist during CRCE integration stage of study. The agreement in terms of attitudes between male students and that of a chemist is shown in **Figure 7.6.** These analyses on male students showed that the attitudes of male students were consistently like that of a chemist. All categories showed positive shifts for all analyses, evidencing the impact of implementation of CRCE modules on students' attitudes. Moreover, the positive shifts for all analyses in the integration stage correspond with that of the implementation stage of the CRCE modules.

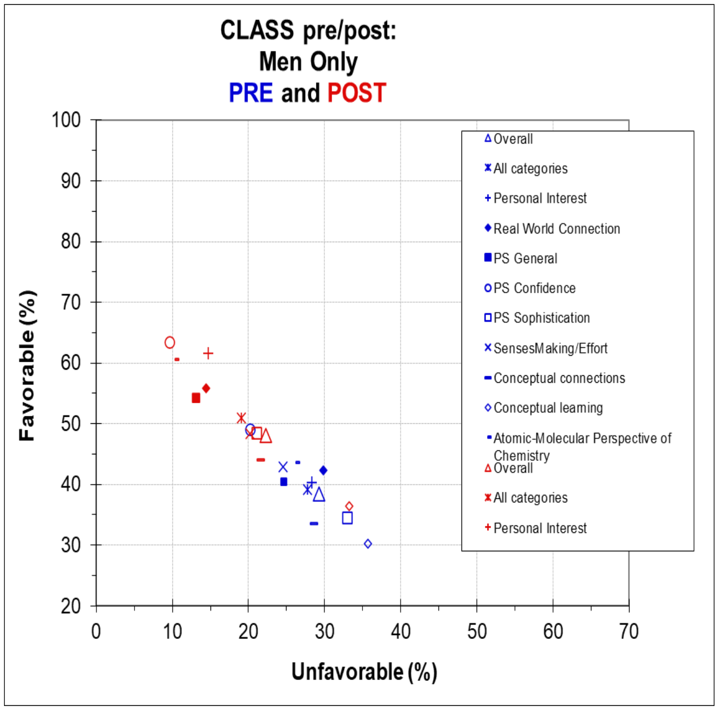

Figure 7.6. Comparison of overall favorable scores for the male students pre and post CRCE modules integration for each subscale of CLASS -Chem.

In general, it was seen that all the 63 students' attitudes were impacted by integrated CRCE modules. This increase in students' attitudes is typical for courses where the curriculum explicitly targets development of expert-like attitudes and beliefs[11]. The CLASS-chem survey results show that this class size (N=63) of mostly agricultural students have relatively good attitudes which are quite consistently expert (agreeing with the expert on more than 80% of the statements).

Positive outcomes through integrated CRCE show that the way the modules were integrated, it impacts students' interest in studying chemistry, and enhance students' ability in solving a problem in general chemistry with confidence. Modules also help students connect the real word applications to when learning a concept. These findings are like findings from implementation stage.

7.4.4. Impact of CRCE Modules Integration on Student Motivation and Engagement

The impact of integrated CRCE modules on student motivation and self-regulation was investigated through SALES data. Based on the success of CRCE modules in the implementation stage, it was anticipated that CRCE module integration could positively impact student motivation and self-regulation. Overall, 68 students completed the pre and post SALES questionnaires. In SALES 32 item survey, each item is based on 5 point Likert scale, indicating the degree of agreement with a statement in the order; 1= strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree. The survey measures four factors of student motivation; Learning Goal Motivation (LGO), Task Value (TV), Self-Efficacy (SE), and Self-Regulation (SR). Mean scores and standard deviation for these subscales measuring student motivation mean and values were calculated and were compared using paired samples t-test. The effect size between each subscale pre and post was calculated. This result is presented in **Table 7.19.**

Table 7.19. Descriptive and Inferential Analyses of CRCE modules on student's motivation and self-regulation.

SALE Survey (Category)	Pre-SALE Response (N= 68)		Post-SALE Response (N= 68)		Paired-t-test value	*p-value*	Effect Size
	Mean	S.D.	Mean	S.D.			
LGO	3.89	0.52	4.28	0.43	-3.29	0.00065	0.82
TV	3.30	0.65	3.80	0.30	-3.69	0.00016	0.99
SE	3.56	0.63	4.04	0.50	4.91	< 0.0001	0.84
SR	3.63	0.58	4.01	0.49	3.37	0.00049	0.71

From the results, an increase in mean values with significance from the pre to post was witnessed for all the four categories. There was a positive shift in students LGO mean

± standard deviation from pre (3.89 ±0.52) to post (4.28 mean ± 0.43). Pre mean ± standard deviation for TV, SE and SR also showed positive shifts in each subscale mean scores. Also, analysis on all four SALES categories show a larger effect size between each subscale from the beginning of the semester to the end of the semester. Further analysis on mean scores for the four categories set at 0.05 showed significant difference for LGO mean values (p value =0.00065), TV (p = 0.00016, SE (p-value < 0.0001, and SR (p = 0.00049). Positive outcomes during integration of CRCE modules show an impact of modules integration on all categories (Leaning Goal Orientation, Task Value, Self-Efficacy, and Self-Regulation) measuring students' motivation and self-regulation.

To confirm the results above, the cumulative score for each category measuring motivation and self-regulation was determined. There was an increase (from 25 to 35) in number of students with high Learning Goal Orientation at the end of the semester. At the beginning of the semester, the extent to which the seven students perceived themselves to be learning, and mastering the concepts needed an improvement. This number reduced to three, showing the impact of integration of CRCE modules on LGO. Same results were witnessed for Task value. The number of students who had high task value increased from 10 to 19 from the beginning to the end of the semester, showing student's appreciation to perform the assigned task. Under Self-efficacy, there was a positive shift in number of students with high self-efficacy from 9 to 13. Self-regulation category also showed an increase in number of students with high self-regulation.

The number of students with high self-regulation increased from 18 to 27 at the end of integration stage. This analysis explains that the degree to which the students were regulating and controlling their efforts in learning the chemistry content was high. Results from this analysis is presented in **Figure 7.7**.

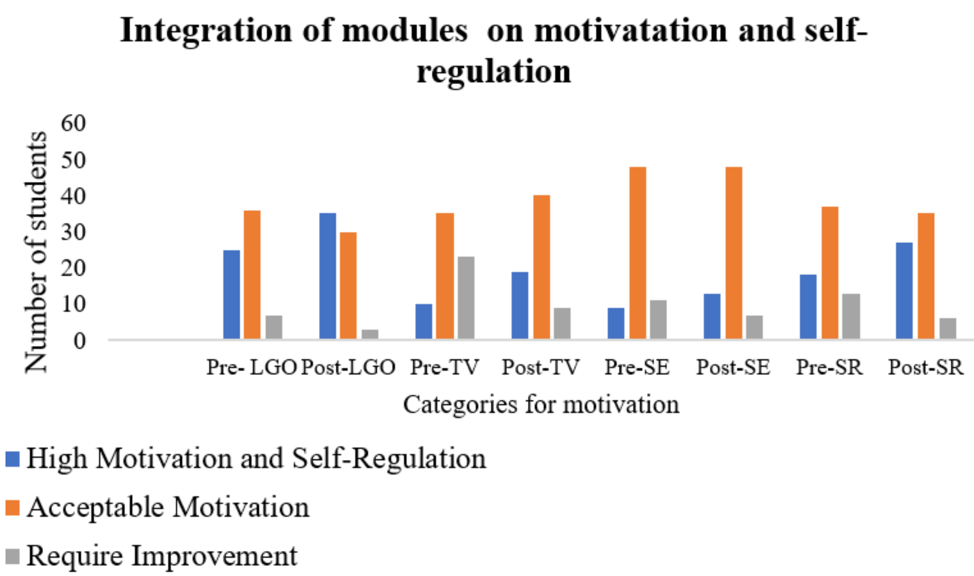

Figure 7.7. Impact of CRCE Integration on Students Motivation and self-regulation.

Overall, results from integration of CRCE modules agree with the results obtained during implementation of CRCE modules. Both analyses show that indeed the CRCE modules had an impact on students' motivation and self-regulation. Despite, a change in instruction in the middle of the spring semester, students' overall motivation and self-regulation were very encouraging.

7.4.5. Students' Perception and their Experiences with Integrated CRCE Modules

CRCE survey was conducted to analyze student perception and experience of the CRCE modules in the integration phase. A total of 103 responded to this survey. A summary of survey results is provided in **Table 7.20.**

Table 7.20. Summary of student responses to CRCE survey items.

Items	Mean	S.D.	% (N) Strongly agree	% (N) Agree	%(N) Neither agree nor disagree	% (N) Disagree	%(N) Strongly Disagree
1	3.73	0.90	21.4(22)	43.7(45)	25.2(26)	5.8(6)	3.9(4)
2	3.75	1.10	27.2(28)	39.8(41)	15.5(16)	15.5(16)	1.9(2)
3	3.93	1.10	35.9(37)	37.9(39)	15.5(16)	4.9(5)	5.8(6)
4	3.95	1.00	28.2(29)	50.5(52)	12.6(13)	5.8(6)	2.9(3)
5	4.02	1.10	36.9(38)	44.7(46)	7.8(8)	4.9(5)	5.8(6)
6	3.98	1.10	35.0(36)	44.7(46)	8.7(9)	6.8(7)	4.9(5)
7	4.10	0.98	39.8(41)	40.8(42)	11.7(12)	4.9(5)	2.9(3)
8	3.93	1.02	33.0(34)	39.8(41)	17.5(18)	6.8(7)	2.9(3)
9	3.72	1.07	20.4(21)	51.5(53)	13.6(14)	8.7(9)	5.8(6)
10	3.47	1.10	13.6(14)	45.6(47)	22.3(23)	10.7(11)	7.8(8)
11	3.59	0.89	11.7(12)	48.5(50)	30.1(31)	6.8(7)	2.9(3)
12	3.92	0.91	23.3(24)	56.3(58)	13.6(14)	2.9(3)	3.9(4)
13	3.91	1.13	36.9(38)	34.0(35)	18.4(19)	4.9(5)	5.8(6)
14	3.60	1.08	21.4(22)	37.9(39)	25.2(26)	10.7(11)	4.9(5)
15	3.98	0.99	32.0(33)	46.6(48)	11.7(12)	6.8(7)	2.9(3)
16	4.11	0.86	32.0(33)	55.3(57)	7.8(8)	1.9(2)	2.9(3)

Based on results, 57 students agreed that modules that connect traditional practices with modern sciences are needed. Thirty-five (35) students agreed to the role of indigenous knowledge increasing their intellectual curiosity to study chemistry. When students were asked if indigenous or traditional practices and modern scientific approaches represent a continuum of scientific knowledge, 50 students agreed to this statement. Few students, 3 out of the whole population (103) disagreed to the cultural knowledge being used to draw connections to current scientific practices. Students who agreed to chemistry being applicable to their everyday activities and that of their ancestors, and that studying chemistry helps one to gain knowledge that will be useful in life outside school were 39 and 45. From students' responses, it shows how integrated modules, connecting traditional practices with modern sciences are needed.

The results agree to results obtained during implementation of CRCE modules where 55% (23) of students strongly agreed and 33% (14) also agreed that they would like to see more modules and resources in chemistry that make use of examples connecting cultural practices with modern science.

Based on students responses, it shows that students after going through CRCE modules perceive the modules to impact their academic performance, conceptual understanding, attitudes, and motivation and self-regulation as evidenced by the students' performances, students' discussion posts, and students responses to ASCI, CLASS-Chem and SALES surveys.

Apart from understanding students experience with modules, there was the need to assess students' ability to transfer and incorporate scientific knowledge from integrated modules. Results on this analysis is presented below.

7.4.6. Analyzing student's ability to transfer and incorporate scientific knowledge from integrated modules

Students were interviewed to evaluate student perception of the integration of CRCE modules as additional evidence for the effectiveness of modules for student learning. Among the 20 students who were interviewed, 12 were males and 8 were female. Most of the students (15 students) were majoring in agricultural science. Two students were majoring in health science and the remaining three students were majoring in other majors. There were 17 Caucasians, 1 Native American, 1 African American, and 1 Asian. Among the participants, 12 respondents perceived learning science as challenging based on their experience in science courses. Also, 8 students answered that their experience with science was very interesting. Students' quotes to this question is shown in **Table 7.21**.

Table 7.21. Student experience of learning science.

Response	Number of Respondents (N)	Quotation 1	Quotation 2	Quotation 3
Challenging	12	For me, chemistry concepts are harder than others to learn. It all depends on the subject.	I have always struggled with learning science as a student.	I personally never enjoyed taking science classes because they all seemed boring, other than physics.
Interesting	8	Always fun and educational	It is interesting to me; I am not very good at Science in general. Overall a big learning cycle.	It has been very interesting, and I have learned so much!

Students initial feeling learning the subject chemistry was also probed. Answers to this question show that most of the respondents initially had negative feeling about chemistry prior to the chemistry survey course. 13 respondents felt chemistry is a scary subject while only 1 student answered that the initial feeling on chemistry was fun (**Table 7.22**).

Table 7.22. Initial Feeling about Learning Chemistry.

Response	Number of Respondents (N)	Quotation 1	Quotation 2	Quotation 3
Chemistry is Difficult	6	it was hard and complex.	my initial feeling learning chemistry was wow this is hard.	The initial feeling was this is difficult, but I passed the class.
Chemistry is Scary	13	At first, I was scared, but I feel slightly more confident now.	I did not want to. Very scared. Kind of wish it were not mandatory	I was scared, but I am glad I took the course
Chemistry is Fun	1	I had a great chemistry course in my high school that I felt prepared me enough for this course, but a few of those concepts we learned were very new and difficult with the online platform. Chemistry is not my favorite subject by any means, so I was nervous and not very enthused. I do not feel like I have any big regrets.		

Students shared their experience with topics that were interesting in the classroom. Examples of concepts that students provided during the interviews were grouped under 3 categories: topics not covered in modules, topics covered in modules, and all topics. Five students saw all topics to be interesting. 4 respondents mentioned concepts which were not covered in the modules and these were grouped under topics not covered in modules. Nine students stated concepts like enthalpy and solutions to be very interesting. All these examples were grouped under one category and are presented in **Table 7.23**.

Table 7.23. Topics students reported to be interesting.

Response	Number of Respondents (N)	Quotation 1	Quotation 2	Quotation 3
All of them.	5	Mostly all of them.	I feel like the first 7 chapters went well	Most of the chapters
Topics not covered by Modules	4	Balancing equations	Lewis dot structures	orbitals, and mass and conversions
Topics covered by modules	9	Enthalpy/entropy	I liked mixing chemicals	Periodic table, types of reactions, chemical reactions, and acids and bases.
Anything math related	2	I enjoyed the topics that involved mathematical formulas, such as Ch. 10 and Ch. 9 and Ch. 8.	Anything math related went well I would say.	

Students were asked if they make connection between chemistry learning and their everyday activities. Among the respondents, 5 students answered that they do not make any connection unless the concept is very specific that they should link it to their everyday activities. Majority of the students (15 respondents) answered that after going through the modules, they make the connection when they are studying (**Table 7.24**).

Table 7.24. Connecting learning to everyday life.

Response	Number of Respondents (N)	Quotation 1	Quotation 2	Quotation 3
No connection unless very specific	5	I usually do not unless if it is something very specific like talking about data pulled from a spreadsheet.	I did not realize how much chemistry is used Daily.	not generally, although I see how it can be connected now that I have taken the class
Connect everything in most activities	15	I am a person that likes to connect everything together in most of my courses. However, the modules made me connect chemistry more to everyday life, especially when we went into the types of reactions, acids, and bases. I like the history aspects of every subject, so I feel like I usually connect my learning to things I do in my life.	I will connect it to my everyday life because I will have to use it when it comes to nursing	There is a lot of chemistry in agriculture.

Students who were interviewed were asked if they already had the knowledge of cultural practices and traditional applications of chemistry before they experienced the modules. From **Table 7.25,** most of the students (18) said they had no knowledge on traditional applications in chemistry before taken the modules. Only 2 students answered that they were very knowledgeable when it comes to traditional applications in chemistry before they even took the modules.

Table 7.25. Knowledge of cultural practices and traditional applications of chemistry before experiencing modules.

Response	**Number of Respondents (N)**	**Quotation 1**	**Quotation 2**	**Quotation 3**
Knowledgeable	2	I had taken chemistry in high school, so I had some previous knowledge of it	somewhat knowledgeable. although I look very Caucasian my family is related to the Indian chief little crow.	
No Knowledge on traditional applications of chemistry	18	I knew nothing about the cultural practices and traditional applications of chemistry	Before these modules, I had not really thought about how different kinds of people used concepts like acids and bases or different measurements. I did not know a whole lot specifically.	I guess that is one thing that I never took into consideration. It was fun to see the difference ways that chemistry is used.

For the advantages of learning about chemistry from a cultural standpoint, 9 students answered that it helps in connecting the studying of chemistry to real-world applications. Three students answered that learning chemistry from the cultural standpoint makes it interesting and relevant. Six students said it gives one different perspective on things. Two students said it helps them to appreciate the study of chemistry (**Table 7.26**).

Table 7.26. Advantages of learning about chemistry from a cultural standpoint.

Response	Number of Respondents (N)	Quotation 1	Quotation 2	Quotation 3
Appreciation of chemistry	2	I think it helps one appreciate their ancestors and the lands ancestors more than they would have.	Help us appreciate our culture and understand that this has been going on for many years.	
Connecting chemistry to real world applications	9	It allows the student to bring it back to their personal lives and helps students learn more by relating things.	you can put it into real life situations	You can apply it in your everyday life
Different Perspective	6	Learning about chemistry from a cultural standpoint can help people connect different ideas together and bring certain cultures together because of the many similarities that they have. Everyone does chemistry in their daily lives, but it allows everyone to learn more about other people in	You learn new things. You combine science with history and that is not done too often	it helps us not only learn about chemistry but culture too

		general, which might not be done otherwise.		
Interesting and Relevant	3	Knowing how it can benefit your life and everyday living.	it makes chemistry more interesting and makes me want to learn it. it also shows how we as humans have come so far over time.	It makes it more relevant

In terms of the difficulty level of the modules, 8 and 2 students answered the modules were easy and very easy respectively. Seven respondents said they do not regard the modules as neither difficult nor easy (**Table 7.27**). Two students said the modules were very difficult. Follow-up question to why students gave these responds was not asked during the interview.

Table 7.27. Difficulty Rate of Modules.

Response	Number of Respondents (N)
Very Difficult	2
Difficult	2
Neither difficult nor Easy	7
Easy	8
Very Easy	1

Based on the student interview data, it appears that modules were beneficial for helping students connect the chemistry content with cultural practices and see the chemistry content considering its relevance to everyday applications. Perhaps students decline in fear as shown in the ASCI survey can be attributed to the use of CRCE modules, and connecting it to students responses in these interviews, one can say that students had overall a positive perception of chemistry due to the integration of CRCE modules.

7.5. Conclusion on CRCE Integration

This chapter focused on the impact of integrated CRCE modules in the general chemistry course. Research questions on students' attitudes, motivation and self-regulation, academic performance, and conceptual understanding were addressed following up from the piloting and implementation stages. Results have shown that

a) Students showed an improvement in their academic performance as evidenced from student performance in quizzes, standard tests, and exams during integration of CRCE modules.

b) The integration of CRCE modules as evidence from the results of students' discussions posts, and qualitative interviews indicate that students could relate chemical processes and principles to everyday activities. The CRCE modules contributed to both the cultural and scientific awareness and simultaneously impacted student conceptual understanding.

c) Based on results from CLASS-Chem survey, overall students attitudes showed a positive shift with respect to personal interest, real world connection, PS: general, PS: confidence, PS: sophistication, sensemaking/effort, conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry. From the ASCI analysis, there was an increase in students' utility and interest but a decrease in students' emotional satisfaction as well as intellectual accessibility from the pre to the post. Although there was a decrease in students fear (not significant), their anxiety increased with minimal effect. This may be as a result that students were anxious and afraid due to the pandemic, thus affecting their learning from home.

d) Overall, student motivation and self-regulation in chemistry showed positive shift with the integration of CRCE modules. Analysis on all four SALES categories show a larger effect size between subscale means from pre to post with significance set at 0.05 showing difference for LGO, TV, SE, and SR mean values.

7.6. Limitations and future work

The COVID-19 disease disrupted the face-to-face class, and class was transitioned to online learning during the spring 2020. This resulted in a significant decrease in survey and exams participation. Besides these limitations, the study was completed successfully, and the research questions focused on the impact of integration of CRCE modules have been reasonably answered for each research question.

There are myriad ways in which the data can be analyzed to triangulate the findings. These are some avenues that remain to be explored and addressed in the future work.

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CHAPTER EIGHT

OVERALL CONCLUSION AND THE IMPLICATIONS OF CRCE STUDIES FOR THE CURRICULUM DEVELOPMENT

8.1. Summary

The development and study of the effectiveness of the CRCE modules involved the three stages of piloting, implementation, and integration. As explained in the introductory chapter, a major gap in the CRE is the availability of culturally relevant curricular materials in chemistry that support such student-centered approaches[1-3]. To address this gap in literature, student-centered modules focused on CRCE were developed on various topics that are covered in a first semester of a general chemistry course at the college level. The effectiveness of these modules was studied in three district stages of piloting, implementation and integration using a sequential exploratory research design[4]. The research questions for this project focused on the impact of the CRCE modules in chemistry on a) student academic performance as evaluated by hour exams, cumulative final exam, and cumulative standard tests, pre and post quizzes b) conceptual understanding as determined by analysis of qualitative students' discussion posts, semi-structured interviews and CRE survey c) student attitudes as measured by CLASS-Chem and ASCI surveys, and d) Student motivation and self-regulation in science (chemistry) as evaluated by SALES survey.

Table 8.1 summarizes the difference in the impact of the developed CRCE modules throughout the semester study was conducted. It is important to note that the mixed results of the integration of CRCE may result from some adaptation due to the COVID-19 pandemic. Although there was an inconsistency of impact of integrated CRCE modules on students' attitudes toward chemistry reported, but most of the principles prescribed for CRCE integration were observed during the integration stage, modules were integrated in the lecture only for short time frame (January-March 2020). The course was taken to online mode due to the pandemic, which might explain the few differences observed.

Table 8.1. Summary of Outcomes from CRCE Study

Variables	**Results during Piloting**	**Results during Implementation**	**Results during integration**
Academic performance	Increase in average scores though not statistically significant	Improvements in students' assessments.	Improvements in students' assessments.
Conceptual understanding	Positive impact in general chemistry	Positive impact in general chemistry	Positive impact in general chemistry
Attitudes toward chemistry	Inconclusive positive trends in some categories but not all for CLASS Survey	Positive Impact from CLASS and ASCI Surveys	1.) positive trends in some categories but not all for ASCI 2.) Positive Impact from CLASS
Motivation and Engagement	Positive impact in general chemistry	Positive impact in general chemistry	Positive impact in general chemistry

Based on the results presented in each of the chapters 5-7, it appears that overall, the CRCE modules were effective.

8.2. Implications for Research

No prior studies have yet explored the impact of CRCE modules using any of these valid and reliable instruments. Exploring various adaptations of CRCE modules and their impact on students' academic performance, conceptual understanding, attitudes, and motivation and self-regulation could lead to a better understanding of the components of CRCE modules that contribute most to improving student academic performance, conceptual understanding, attitudes, and motivation and self-regulation. Further studies will be needed to explore the relationships between quality of implementation and integration of CRCE and impact on these variables. Studies should also investigate whether factors, such as students' consistency with reading and watching videos of modules, and how instructors integrate CRCE in their learning materials can be done.

The time frame of CRCE study could explain the mixed results. Results obtained from this study indicate that instructors implementing or integrating CRCE modules should not presume all expected outcomes after their first implementation or integration. It is recommended that CRCE studies should be carried out over a long period of time or after piloting the practices for a couple of semesters. Series of studies to investigate the evolution of impact of CRCE modules over time would inform practitioners interested in adopting these modules for a specific time frame before impacts can be observed.

In reference to this study, it shows a delay may exist between first implementation or first integration and positive outcomes for students. The striking results from this study was the positive impact of CRCE on students' conceptual understanding, and motivation and self-regulation throughout the entire studies (from piloting stage to integration stage). To my knowledge, this connection has never been studied before and may merit further study. Indeed, the conceptual understanding, and motivation and self-regulation of CRCE students as witnessed via students' discussions posts are desirable outcomes that are difficult to achieve with traditional teaching styles. However, the design, implementation, and integration of modules highlights several factors that instructors interested in this practice should be aware of.

Adaptations to the prescribed integration and implementation may affect the expected impacts on students. Hence, instructors should meticulously inform themselves about the prescribed implementation, and integration of CRCE. Interested instructors can also go through the piloting, implementation, and integration of modules as well as the appendix as resources for implementation and integration. Careful analyses will help instructors identify approaches to implement or integrate CRCE modules to fit their context while considering CRE principles.

Both present implementation and integration of CRCE modules demonstrate that CRCE modules have the potential to impact student academic performance, conceptual understanding, attitudes, and motivation and self-regulation toward chemistry. The outcomes from this study along with underlying principles of CRCE modules, which are based on established theoretical frameworks, should encourage instructors to test CRCE in their classrooms. Similar educational modules can be developed in other concepts, as many of the fundamentals of the modules are applicable to other concepts in chemistry and other disciplines. The only recommendation is that such modules should follow similar pathways undertaking for many educational modules including those presented in these chapters.

8.3. References

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APPENDIX 1

General Course Information	
	General Chemistry Survey Course Syllabus
Course Title	CHEM 106: Chemistry Survey – Spring 2020
Time	Monday, Wednesday, Friday 3:00-3:50 PM
Section	01
Credit	3
Pre-Requisite: Math 102 or higher	Co-Requisite: CHEM 106L
First Day of Class:	January 13th, 2020 (Mon.).Last Day of Class: May 1st (Fri.)
Course Instructor:	Dr. Tanya Gupta (Dr. Gupta)
Office	SAV 361

Course Textbook:

Fundamentals of General, Organic and Biological Chemistry, 8th Edition, John E. McMurry, David S. Ballantine, Carl A. Hoeger, Virginia E. Peterson, Pearson Publishing AND *Mastering Chemistry*. The text can be accessed through D2L and e-text is available through Vital Source Bookshelf link in D2L (under Getting Started). Refer to D2L for more details (and to email sent to all students by university for text access and availability). Course Code for CHEM-106 is PSCMGE-NEUSS-MILNE-REVET-TANIS-LOOSE.

Lecture location:

Section S01: Monday/Wednesday/Friday: 3:00 – 3:50 pm in Rotunda D

Office Hours: Wednesday 4:00– 5:30 pm or by appointment

Chemistry Resource Room: SAV 247 – graduate students available to answer your questions (lab and lecture).

Generally available Monday through Friday, 10 am to 5 pm (check SAV 247 door for specifics)

Course Description:

One-semester introduction to chemistry. Not intended for those needing extensive chemistry background. Duplicate credit for Chem106 & Chem112 not allowed; *Co-requisite: Chem. 106L. Pre-req.: Math 101 or 095.*

ABOUT THE COURSE

Course Objectives:

This is a one-semester survey of chemistry. The course is *not intended for those needing an extensive chemistry background*. *Course involves an introduction* to the properties of matter, atomic structure, bonding, stoichiometry, kinetics, equilibrium, states of matter, solutions, and acid-base concepts. While not comprehensive, it will help students understand and appreciate the role of chemistry in the world around us.

1. **Course Goals & Outcomes:**

This course fulfills the System General Education Goal #6 (Natural Sciences): Students will understand the fundamental principles of the natural sciences and apply scientific methods of inquiry to investigate the natural world. As a result of taking this course, students will:

A. Demonstrate the scientific method

- To meet this outcome, students will apply the scientific method to explore problems in general chemistry.
- This outcome will be assessed through assignments, quizzes, exams, laboratory experiments and class discussions.

B. Critically evaluate data using the scientific method.

- To meet this outcome, students will use sound scientific concepts and principles.
- This outcome will be assessed through in class problems exams, chapter review problem sets, homework and class discussions

C. Identify and explain the basic concepts, terminology and theories of selected natural sciences.

- To meet this outcome, students will identify and explain basic concepts in chemistry.
- This outcome will be assessed through in class problems exams, chapter review problem sets, homework and class discussions

D. Apply selected natural science concepts and theories to contemporary issues.

- To meet this outcome, students will utilize lecture and laboratory principles to evaluate topics of current interest. To increase the awareness of the significant and central role chemistry plays in life and to stimulate curiosities about the science in general.
- This outcome will be assessed through in class problems exams, chapter review problem sets, homework and class discussions

Course Websites: This course uses two websites; Desire2Learn (D2L) and Pearson Mastering Chemistry. You can access Mastering Chemistry through D2L. Your e-text for first day access (all students are automatically enrolled for first day access as notified via email by the SDSU campus bookstore) can also be accessed through D2L.

Desire2Learn (D2L): D2L will be used to post all course materials, class announcements and grades. To access your D2L account, go to: http://d2l.sdbor.edu. Your username and password are the same you use for WEBADVISOR. Access to D2L is

REQUIRED. I will also use D2L as a way to convey announcements/changes/etc. so it is highly advisable that you visit it on a regular basis. D2L app (Brightspace Pulse) is also available for students. Please download this app on your Internet connected device.

Mastering Chemistry: Mastering Chemistry (MC) is a website that accompanies the textbook and will be used to complete all homework assignments and managing homework score. It provides many useful resources in addition to being used to complete the required assignments. To access Mastering Chemistry, see the instructions on the posted on D2L. In addition to required course assignments, the Study Area within Mastering Chemistry provides additional practice questions, math reviews, and tutorials that can help you successfully complete this course.

Turning Point Clickers: These will be used for in-class assessment. Students need to purchase and register their clicker device so that their class participation scores can be added to the grade book.

Email Correspondence: All email correspondence will be done with the home university assigned email. It is strongly advised to only use your Jacks email. Any other email address may be automatically sent to my spam folder without my knowledge and this folder is not checked frequently. Please make sure that all emails you send include which class you are referring to in the subject line (**chem 106**) and that you are clear, concise and courteous in your message. Please use tanya.gupta@sdstate.edu for all correspondence.

Academic Honesty/Dishonesty Policy: Student Academic Integrity and Appeals: The University has a clear expectation for academic integrity and does not tolerate academic dishonesty. University Policy 2.4 sets forth the definitions of academic dishonesty, which includes but is not limited to, cheating, plagiarism, fabrication, facilitating academic dishonesty, misrepresentation, and other forms of dishonesty relating to academics. The Policy and its Procedures also set forth how charges of academic dishonesty are handled at the University. Academic Dishonesty is strictly proscribed and if found may result in student discipline up to and including dismissal from the University. *It is strongly recommended that you review the Student Conduct Code located under the SDSU Getting Started page.*

Disability: Any Student who feels s/he may need an accommodation based on the impact of a disability should contact Nancy Hartenhoff-Crooks, Coordinator of Disability Services (605-688-4504 or Fax, 605-688-4987) to privately discuss your specific needs. The Office of Disability Services is located in Room 065 of the SDSU Student Union.

Freedom in Learning: Students are responsible for learning the content of any course of study in which they are enrolled. Under Board of Regents and University policy, student academic performance shall be evaluated solely on an academic basis and students should be free to take reasoned exception to the data or views offered in any course of study. Students who believe that an academic evaluation is unrelated to academic standards but is related instead to judgment of their personal opinion or conduct should first contact the instructor of the course. If the student remains unsatisfied, the student may contact the Department Head, Dean, or both, of the college, which offers the class to initiate a review of the evaluation.

Instructional Methods: This course will involve class lectures, problem-solving activities, discussions, online homework (Mastering Chemistry), and in-class exams. It is strongly recommended that any suggested activities you can do outside of class to strengthen your understanding of the material be attempted. This course will require you to complete reading outside of and prior to class in order to obtain fundamental knowledge about the subject matter. Tentative schedule for material is provided in syllabus and it is expected that students will read sections of chapter from the text before coming to class. This will allow the in-class time to be used more effectively to show applications of these concepts to real-life situations and examples and do more problem-solving activities.

Attendance and Absences: Attendance at lecture is expected, but not required; however, be aware that graded clicker questions will be asked during lectures in class and it is your responsibility to find out what was missed from classmate if you miss lecture. Excused absences are given only for a university-sponsored event, a death in the family or personal illness. For all situations, you are required to show proof of the event. To obtain an excused absence, email me your request with documentation attached in the email and a short explanation as to the reason for your absence. If you will know of your absence prior to class, the request must be submitted at least 24 hours prior to the absence. If it is an unplanned absence, the request must be submitted within 48 hours of the absence. Once I have your email with the needed document, I will provide a slip for you to make-up missed clickers during my office hours or by appointment.

Methods of evaluation and graded activities in the course

Methods of Evaluation: Chemistry 106 will be assessed on the basis of homework assignments, CRCE modules quizzes and discussions, class participation and exams. **There may be a few extra credit activities, which will be announced in advance.**

Homework: You will have an assignment for each chapter of the text that is covered in class (Chapters 1 through 10) and an introductory/math assignment. Homework assignments will be completed in Mastering Chemistry. The due dates for these assignments can be viewed in the calendar on Mastering Chemistry and will be posted to D2L. The assignments are designed to be a review of each chapter, but it is recommended that you work on these throughout the period of time that we are discussing each chapter to help you understand the topics. You will get six tries on each question so if you incorrectly complete a question, you may go back and resubmit your answer. Each HW is worth 15 points. The Mastering Chemistry system will automatically deduct 5% points/ day for late submission of HW on this system. For example, if you complete HW, one day after the due date and your score was 100%, due to late completion you will receive 95% on that HW. Please make sure to complete all assignments by the due dates to avoid late penalties. (as per syllabus or in the event of change by the new dates). **Table S5** has tentative due dates listed.

CRCE Modules: CRCE (Culturally Relevant Chemistry Education) modules are an informal approach to expand your understanding of the content covered in class with respect to its applications in modern and traditional world. There are five modules overall that broadly cover the 10 chapters from the syllabus (chapters 1-10 of textbook). Each module is accompanied by a text-file and a brief video. Each module is also followed by a quiz that will be worth 5 points (total 25 points for the semester). Students are expected to read the text file and watch accompanying videos which will be posted on D2L. Following the reading and video review, students will engage in D2L discussion (see information on D2L Discussion in next paragraph) and complete the quiz. **There are overall five CRCE quizzes based on five modules.** At the end of the modules there will be a cumulative CRCE module final quiz on D2L covering modules 1-5 to assess student understanding

(32 points).

D2L discussion forms: There will be a discussion topic created from various CRCE modules. Overall there will be 5 discussions based on 10 chapters covered in class (1-10). There will be prompts posted for each module for discussion on D2L. Students will be making at-least one post (starting a new post), reading at least 2 posts and responding to 2 posts of peers to obtain full credit. Note that the purpose of this assignment is for the student is to foster a collaborative exchange of their viewpoints and communication on explanations of ideas presented in CRCE modules. The discussion topics will remain open till a specific date and close after the chapter is completed in lecture. Please pay attention to the announcements in class and D2L news regarding the content and due dates of each module, module quiz and HWs. Check D2L calendar and news section for opening and closing dates (due dates of assignments - quizzes, homework assignments, D2L discussion forum, exams etc.).

General expectations for assessment of D2L discussion are presented in Table S1 and Rubrics for qualitative assessment of discussion are presented in Table S2.

Table S1. General Rubric for Discussion posts for each Module

10 points	5 points	0 points
Make 1 post, reply 2, and read at least 2 posts	Makes 1 post, reply 1 post, and reads at least 1 post	Makes no posts, replies no posts and only reads (or either reads no post)
Deductions: -2 for any of the following: irrelevant or off-topic discussion; improper English; use of text message jargon.		

Table S2. Rubric for qualitative assessment of D2L (online) discussions among students

Category	10	5	0
Timely Discussion Contribution and Collaboration	The student contributes and responds regularly and on a timely basis. (1 post, 2 reads and 2 replies) in response to discussion prompts for the topic.	The student contributes and responds occasionally and on a timely basis. (1 post, 1 read and 1 reply) in response to the discussion prompts for the topic.	Does not contribute or respond to discussions on a timely basis. (only reads, no posts and no reply). The response does not correspond to the discussion prompt.
Quality of Information	Postings contain information that conveys a deep understanding of the main topic and detailed response to discussion prompts.	Postings contain information that conveys some understanding of the main topic but the response to the prompts is shallow.	Postings do not convey an understanding of the main topic or there is no coherent response to the discussion prompt.
Critical Thinking	The student consistently demonstrates and promotes critical thinking and connects the text and lecture notes to the module.	The student frequently demonstrates and promotes critical thinking. There is some connection of the text and lecture notes to the module.	The student does not demonstrate critical thinking. There is no connection of the text and the notes to the module.
Contribution to the Learning Community	Consistently attempts to motivate the group discussion, presents creative approaches to the topic.	Frequently attempts to direct the discussion and to present relevant viewpoints for consideration by the peers.	Does not express opinions or ideas clearly; no connection to the topic.
Professional Language/Adherence to Online Protocols	All postings add value to ongoing discussion and provoke further discussions; posts and replies are written using proper English,	Most postings add only a little value to ongoing discussion and just provoke nominal yes/no type continuity of discussions; posts	Does not add value, no thought-provoking discussion, use of jargons, improper English and poor scientific sentence structure

	scientifically logical sentence structure, and complete words and sentences.	and replies use improper English, scientifically illogical sentence structure with incomplete words or sentences.	

Class Participation: Class participation will be evaluated using practice questions delivered via Clickers. These questions will cover your understanding and applications of material covered in class or based on reading of the text and the CRCE modules. Points for Learning clicker questions are awarded for the correctness of responses. The number of questions will vary daily. If a student missed a class due to university event or other reasons a student must provide a document through (email – a picture or scan of document supporting excused absence) and make up the missed work within 2 weeks of absence when student returns. It is responsibility of student to contact the professor and to ensure that they make-up for any missed work within the two weeks of their absence from class. You need to get instructor approval to make-up for missed clicker questions for an excused absence. Please check with me before or after the class – based on your documentation of excused absence, I will assign you a make-up slip so that you can make-up missed clicker points during my office hours or by appointment. It is expected that you will bring the make-up slip along with when you come to my office for make-up of clicker questions.

Exams: There will be 4 exams covering various chapters and a cumulative final exam. See the Tentative Course Schedule for all exam dates (**Table S5**). All work submitted must be your own work. There are no make-up exams. If you will be gone due to a campus excused absence, you must arrange with me prior to your absence from the exam. All reference information you will need will be provided for you on each exam and will be posted on D2L prior the exam. For each exam you will need a pencil, a non-programmable scientific calculator, and your student ID. You will not be able to keep your exams; however, you are highly encouraged to come to my office hours (or other times by appointment) to view your exam. Exams will only be kept until the next exam is given. It is recommended that you bring the relevant weekly class notes with you so that I can provide feedback on your preparation and performance in course.

Final Exam: The cumulative final exam will be given on Monday *May 4th from 1:45 to 3:45 pm Rotunda D*. It will cover all chapters (till last lecture). No early final exams will be allowed except where required by university policy (such as three or more final examinations fall on the same day) so please plan accordingly.

Table S3. A summary of graded activities and course components that contribute to overall grade

Grading: the final grade will be determined as follows	
Class Participation – clickers	Up to 5 points per day ~ 200 points
Homework – Mastering Chemistry (11 Homework's on MC)	15 x11=165
Exams (1-4) – in class	102 x 4 = 408 points
CRCE-Quizzes	25 points
CRCE D2L discussions	50 points
CRCE module final quiz	32 points
Final Exam – in class	120 points
Total points possible	~ 1000 points
Extra- Credit activities – (in class/ outside)	To be determined

The letter grades will be assigned based on the earned percent score of the Course Total as shown in **Table S5**:

Table S4. Letter grade criteria.

Letter Grade	Percentage Range
A	90.0 %
B	80.0 % - 89.9%
C	70.0% - 79.9%
D	60.0%-69.9%
F	Below 60.0%

Bonus activities/ Extra credit: There may be few bonus activities to help you gain extra-credit points. Students will be provided information for Bonus activities under Bonus activities button in the Content Section of D2L and also during class. These activities will be announced on D2L and via e-mail for their starting and closing dates. Note that these activities will be optional, and students are not required by any means to participate in these. However, as implied these are extra credit. To earn these points, it is expected that students will complete all steps involved as indicated in directions and complete these activities by the due dates announced on D2L. If not completed in time and as per the directions, students will not receive any extra-credit points associated with the bonus activity.

Once graded, all scores will be posted in D2L for each student. Homework scores can also be viewed within Mastering Chemistry. In general, all scores will be posted within a week from the due dates of assignments. If you see an error in the scores posted to D2L or Mastering Chemistry, you have one week from the time the assignment was due or the score was posted to D2L to bring the error to my attention. No modifications to grades will be made after this time period has elapsed.

Late Class Statement: All members of the class should make every effort to arrive on time. In the event that I am going to be late due to unforeseen circumstances, I will, if possible, post an announcement to D2L and notify the Chemistry and Biochemistry Department office to ask that someone be sent to apprise you of the situation. If such notification is not possible, please remain in the class for 15 minutes beyond the scheduled start time. If I have not yet arrived and no emissary of the department has informed you otherwise, class will be considered canceled and you will be free to leave.

Academic Success/ ConnectState Early Alert: As your professor, my goals are to help you be successful in this course and to make your learning experience as meaningful as possible. For that reason, if you demonstrate any academic performance or behavioral problems that may impede your success, I will communicate with you using ConnectState Early Alert. ConnectState Early Alert is an online student success program that allows me to send various performance updates to you and to those dedicated to supporting your success at SDSU. If you receive a notification in Early Alert, please come see me or seek assistance from your advisor, the Student Success Center, or other campus resources. Please make sure to update your ConnectState Early-alert profile at the beginning of each semester (including a photo and up-to-date contact information). The Early-alert link is located in D2L in the top left corner of your homepage.

Instructor Availability: For the duration of course, I will be available through:

a) E-mail at: tanya.gupta@sdstate.edu for individual questions only. (Subject: CHEM 106).

b) *D2L\Communications\Ask The Professor* for subject related questions only. The “Ask the Professor” forum discussed below will be monitored regularly during weekdays. If you have any course related questions, please post these on Ask the Professor D2L forum.

c) Office & Phone: 361, SAV; 605-688-5328: Note that I maintain an active research group and may not be always in my office. If you would like to meet with me, please do so during office hours or schedule an appointment. Email remains the best medium to communicate.

d) I will try to respond to you as soon as I can unless a circumstance forbids speedy communication.

Class Schedule for topics and assessments: **Table S5** provides TENTATIVE dates for various topics, in-class exams and assignments (HW, CRCE Post-Quizzes, D2L discussions, and Exams). Some topics may take longer to cover, and some take lesser time than anticipated. There will be additional surveys and extra credit activities that will be announced on D2L for due dates. Any changes in these dates will also be announced on D2L news, during class, and D2L "Ask the Professor" Discussion Forum.

Table S5: Tentative Class Schedule-Spring 2020.

Day	Day	Date	Topic	Req. Reading: Text section	MC-HW Due on (11:59 PM)	CRCE-Modules Discussion and Quiz (D2L-11:59 PM)
1	Mon.	01/13	CHEM-106-Intro: syllabus and technology	Syllabus	HW0-Intro to MC & Math review and HW#1 Due-1/22	CRCE-Module 1 D2L Discussion 1 Due-1/26 M2- QUIZ-Due 1/26
2	Wed.	01/15	Ch. 1: Matter & Measurements	1.1 & 1.6–1.10		
3	Fri.	01/17	Ch. 1: Matter & Measurements	1.11–1.12		
4	Mon.	01/20	Martin Luther King Holiday			
5	Wed.	01/22	Ch. 1: Matter & Measurements	1.2–1.5		
6	Fri.	01/24	Ch. 2: Atoms & the P.T.	2.1– 2.3	HW# 2 Due 1/30	
7	Mon.	01/27	Ch. 2: Atoms & the P.T.	2.4 – 2.5		
8	Wed.	01/29	Ch. 2: Atoms & the P.T.	2.6 –2.7		
9	Fri.	01/31	Exam 1 – In class – Rotunda D			
10	Mon.	02/03	Ch. 3: Ionic Compounds	3.1 –3.4	HW# 3 Due 02/08	CRCE-Module 2 D2L Discussion
11	Wed.	02/05	Ch. 3: Ionic Compounds	3.5 –3.8		

12	Fri.	02/07	Ch. 3: Ionic Compounds	3.9 –3.11		Due 2/16 & M2- QUIZ due 2/16
13	Mon.	02/10	Ch. 4: Molecular Compounds	4.1– 4.4	HW# 4 Due 02/15	
14	Wed.	02/12	Ch. 4: Molecular Compounds	4.5 – 4.8		
15	Fri.	02/14	Ch. 4: Molecular Compounds	4.9 – 4.11		
16	Mon.	02/17	President's Day Holiday			
17	Wed.	02/19	Ch. 5: Class. & Balancing Chem Rxns	5.1 – 5.3	HW# 5 Due 02/27	
18	Fri.	02/21	Ch. 5: Class. & Balancing Chem Rxns	5.4-5.5		
19	Mon.	02/24	Ch. 5: Class. & Balancing Chem Rxns	5.6		
20	Wed.	02/26	Ch. 5: Class. & Balancing Chem Rxns	5.7		
21	Fri.	02/28	Exam 2 – in class – Rotunda D			
22	Mon	03/02	Ch. 6: Chem Rxns. Mole& Mass Relation	6.1-6.3	HW# 6 Due 03/07	Module 3- D2L discussion Due 03/25 M3- QUIZ DUE -03/25
23	Wed	03/04	Ch. 6: Chem Rxns. Mole& Mass Relation	6.4		
24	Fri	03/06	Ch. 6: Chem Rxns. Mole& Mass Relation	6.5		
25	Mon.	03/09	Spring Break-No classes!			
26	Wed	03/11	Spring Break-No classes!			
27	Fri	03/13	Spring Break-No classes!			
28	Mon.	03/16	Ch. 7: Chem Rxns: Energy, Rates & Eqm.	7.1 –7.3	HW# 7 Due 03/24	
29	Wed	03/18	Ch. 7: Chem Rxns: Energy, Rates & Eqm.	7.4 –7.5		
30	Fri	03/20	Ch. 7: Chem Rxns: Energy, Rates & Eqm.	7.6 – 7.7		
31	Mon.	03/23	Ch. 7: Chem Rxns: Energy, Rates & Eqm.	7.8 – 7.9		
32	Wed	03/25	Ch 8: Gases, Liquids & Solids	8.1 – 8.3	HW# 8 Due 04/04	
33	Fri.	03/27	Exam 3 – In class– Rotunda D			
34	Mon.	03/30	Ch 8: Gases, Liquids & Solids	8.12 – 8.14		
35	Wed.	04/01	Ch 8: Gases, Liquids & Solids	8.4 – 8.7		
36	Fri.	04/03	Ch 8: Gases, Liquids & Solids	8.8 – 8.11		
37	Mon.	04/06	Ch. 9: Solutions	9.1 – 9.3	HW# 9 Due 04/16	Module 4- D2L discussion Due 04/18 M3-Quiz Due-04/18
38	Wed.	04/08	Ch. 9: Solutions	9.4 – 9.6		
39	Fri.	04/10	Easter Recess-No classes			
40	Mon.	04/13	Ch. 9: Solutions	9.7 – 9.9		
41	Wed.	04/15	Ch. 9: Solutions	9.10 – 9.11		
42	Fri.	04/17	Ch. 10: Acids & Bases	10.1 – 10.3	HW# 10 Due 04/25	CRCE- Module 5 D2L QUIZ & discussion Due 04/25
43	Mon.	04/20	Ch. 10: Acids & Bases	10.4 – 10.6		
44	Wed.	04/22	Ch. 10: Acids & Bases	10.7 – 10.9		

34	Fri.	04/24	Ch. 10: Acids & Bases	10.10-10.11		
45	Mon.	04/27	Exam 4 – In Class– Rotunda D			
46	Wed.	04/29	Ch. 11: Nuclear Chemistry			CRCE modules cumulative D2L quiz Due 05/01
47	Fri.	05/01	Ch. 11: Nuclear Chemistry			
48	Mon.	05/04	Cumulative final exam Chapter 1-11 in class from 1:45 – 3:45 PM in class (Rotunda D)			
		05/13	Final Grades Due for submission			

APPENDIX 2

Module 1

The practice of scientific method: Merging the Native Americans view and a contemporary perspective

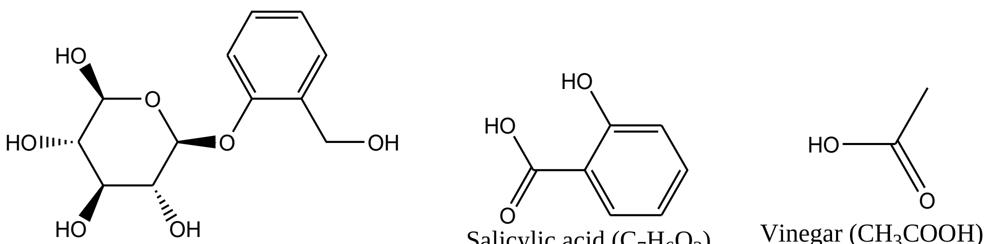
M. A. Fosu and Dr. T. Gupta

Practice of scientific methods within a cultural Native American context predates some western scientific approaches. Though it is barely discussed in classroom, it is important to understand the native practices that have shaped American life in several ways ranging from farming to medicinal practices. By exploring cultural backgrounds and practices that take place over ages, we can achieve a better understanding of science and the practices that are embedded in different cultures and traditions.

Over years, Native Americans have developed a timely and reliable idea of the land, its processes, and the management needs through observation, experimentation, and participation with the natural world. Literatures refer to this native way of knowing as traditional ecological knowledge or simply native science[1]. An appreciation of native science will enable current generation to understand predominant scientific approaches that are intertwined with Native American history, culture, and ecological knowledge.

Science is grounded on experimentation. Early literature in anthropology claimed that Native Americans learned through trial and error. For example, the introduction of new foods among Native Americans involved (a) observation (have we ever seen other people eat this food? Have we observed animals consume same type of food?), (b) research by seeking information (asking others about the food), (c) generation of research question (what is the impact of food on life?), (d) experimentation (will my belly hurt or will my tongue feel numb when I eat this food?). This type of participatory research had a broader impact on native lifestyle and also on the extensive trade routes for generations. Native Americans engaged in environmental management through water, fire, and deliberate cultivation of stands of wild plants. In wooded areas, burning provided new approach in hunting for animals. Fire (burning) was also used by natives to control the forest areas.

The scientific explanation of the use of medicinal herbs and plants by Native Americans focused on chemical components that cause changes in the human body. For example, a therapeutic treatment of aches and fevers was performed by the Iroquois curers in upstate New York who used willow bark tea. The willow bark contains salicin which is now identified as a source of acetyl salicylic acid or aspirin in the modern world[2] (**Figure S1**). The fresh leaves of agave, a species of aloe vera plant was used by the natives to soak and store water for plants during dry seasons (through development of a specialized mode of photosynthesis called crassulacean acid metabolism). The agave root and leaf pulp were used as detergents by many American Indians[3]. Agave was also used traditionally to prepare syrup and sugar by boiling the agave sap. Further, Native Americans fermented the syrup to make vinegar (**Figure S1**).



Salicin ($C_{13}H_{18}O_7$) Salicylic acid ($C_7H_6O_3$) Vinegar (CH_3COOH)

Figure S1. structure of Salicylic acid, salicin, and Vinegar.

Natives Americans also used the sap from the aloe heart as an antibiotic (by increasing bacteria cell osmosis and causing dehydration of cell), laxative, and treatment of sunburns and rashes. Apart from medicinal uses, several other applications of plants and herbs were known to the natives. The fiber from agave plant which consists of a thick cluster layer of gray-green leaves that are 10 to 18 inches long and arranged in a rosette shape was used to make a paper. Henequen fiber, a specie of agave was also used to make twine that was woven into coarse cloth and sandals. Currently, the two most common uses of the agave are aloe vera juices from the aloe plant (as skin soother), and tequila.

Mass and weight are often used interchangeably. Mass is defined as the amount of matter in an object. Weight measures the gravitational force exerted by the earth on the object. Volume, the amount of space occupied by an object cannot be left out. Looking into their chinampas technique, the increase in the temperature and volume of the chinampas are two factors that promote crop productivity by decreasing the density. Temperature is the amount of heat energy present in an object. Temperature often measures in ℃, K or °F (degree Celsius, Kelvin, or Fahrenheit).

Native American were applying chemistry into their everyday activities by observing nature or using their knowledge. Scientists define density of a substance as its mass per unit volume with a symbol of ρ (lower case of the Greek letter rho). Mathematically, density can be expressed as mass divided by volume where other cases can express it as weight per unit volume. Its units are expressed in grams per milliliter (g/mL) for liquids or grams per meter centimeter (g/cm^3) for solids. Density (ρ) =mass(m)/volume(V). If you have access to the materials some of these experiments can be conducted at home and are outlined as follows: Density Determination using ruler and geometry: An example will be determining the density of a metal cylinder made of brass.

1. The mass of the brass object can be found using a balance.

2. The dimensions of height and radius can be measured using a ruler.

3. Calculate the volume of each brass metal piece: cylinder volume = $\pi r^2 h$ (units will be cm^3)

4. Calculate the density of each piece of (g/mL) piece using the mass and volume; recall $1cm^3 = 1mL$.

Density determination by water displacement: for example, using the metal cylinder made of brass

1. Using the same object (brass), calculate the mass of the metal cylinder and record it.

2. A graduated cylinder should be taken empty and fill with water. For example, to the 10.00mL mark. The volume of water that will be displaced after submerging the metal cylinder becomes the volume of the object or for example assuming the water level starts at 10.00mL and changes to 15mL after submerging the metal cylinder, then the volume of the metal cylinder equals the final water volume (15mL) minus the initial water volume (10mL)

3. Calculate the density of the meal cylinder using its mass and volume.

References

1. Elk, L. B., Native science: understanding and respecting other ways of thinking. *Rangelands* **2016,** *38* (1), 3-4.

2. Pierpoint, W., The natural history of salicylic acid Plant product and mammalian medicine. *Interdisciplinary Science Reviews* **1997,** *22* (1), 45-52.

3. Keoke, E. D.; Porterfield, K. M., *Encyclopedia of American Indian contributions to the world: 15,000 years of inventions and innovations*. Infobase Publishing: 2009.

APPENDIX 3

Module 2

The Modern and Traditional Applications of some Ionic Compounds

M. A Fosu & Dr. T. Gupta

Introduction to modern day ionic bonds

In module 1 you learned about matter and measurement with respect to cultural and modern applications. All matter is made up of atoms. Atoms are neutral species. Each atom is unique because it is made of a specific number of protons, neutrons, and electrons. Protons and neutrons are found inside the nucleus of an atom and electrons are outside the nucleus. Protons are positively charged particles, neutrons are neutral, and electrons are negatively charged. Usually, the number of protons and electrons is the same for an atom.

The number of protons never changes for any atom, because changing protons would mean you have a completely different element. The number of electrons of an atom does change. When an atom gains or loses an electron, we get an ion. Since electrons themselves have a net negative charge, adding or removing electrons from an atom changes the charge of the atom. This is because the number of electrons is no longer in balance with or equal to the number of protons, which have a positive charge. Atoms that gain electrons and therefore have a net negative charge are known as ***anions***. Conversely, atoms that lose electrons and therefore have a net positive charge are called ***cations***. Cations tend to be metals, while anions tend to be non-metals. Ions may also be made of single atoms or multiple, complex groups of atoms called polyatomic ions.[1]

When we talk about ions, it's true that opposites attract. The opposite negative and positive charges of the ions hold together in ***ionic bonds***, forming ionic compounds, which are just what they sound like: compounds made of ions. The loss or gain of electrons from one atom matches the loss or gain of electrons from the other atom so one atom essentially 'donates' an electron to the other atom it pairs up with or forms bonds with it.

Traditional practice involving the use of ionic bonding through the interaction of hair conditioner with keratin

Hair conditioner is a hair care product used to improve the feel, appearance, and manageability of hair. Its main purpose is to reduce friction between strands of hair to allow easier brushing or combing[2]. For centuries, natural oils have been used to condition human hair. Pre-Columbian Indians used hair conditioners for the same reason people use them today. They also used botanical hair conditioners to relieve scalp itch and as a dandruff treatment. The Aztec, whose empire was established in about A.D. 1100 in what is now Mexico and parts of Mesoamerica used berries of yiamolli (*phyolacca octandra L.*) to make a conditioner, and extracted oil from sunflower[3].

The Chippewa (*Anishinabe*), who lived in the upper Midwest mixed balsam gum with bear grease. Balsam continuous to be a popular ingredient in modern hair conditioners and shampoos. American Indians living in what is now Southern Arizona, California, and Baja California in Mexico rinsed their hair with conditioners made from jojoba seeds. Jojoba (**Figure S2**) is another ingredient found in many modern shampoos and hair conditioners, it is rich in vitamins, copper, zinc, selenium, and iodine, etc. for ionic bonding-based mechanism of action in the outermost layer of a hair follicle which is called the cuticle. Cuticle is composed largely of keratin[4, 5]. Hair conditioners therefore usually contain cationic surfactants, which do not wash out completely, because of their hydrophilic ends that strongly bind to the keratin. The hydrophobic ends of the surfactant molecules act as a new hair surface.

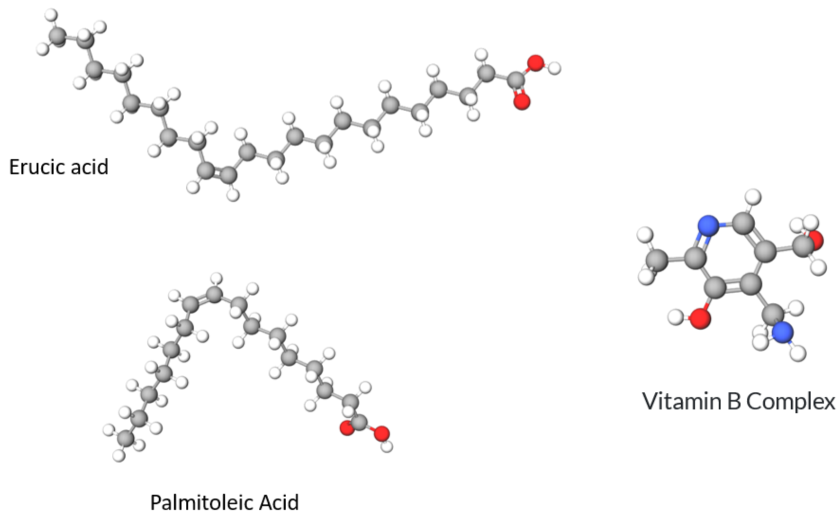


Figure S2. Some major constituents of Jojoba oil

The essential fatty acids (EFA) can help dry or add porosity to hair so that hairs become softer and more pliable. The scalp produces natural oil called sebum. EFA's like the jojoba oil are the closest to the natural sebum (semi-fluid secreted by sebaceous glands in the skin). The surface of keratin contains negatively charged amino acids (rich in cysteine groups which are mildly acidic). When the hair is washed, these groups can deprotonate giving the hair a negative charge.

Positively charged quaternary ammonium species such as ***behentrimonium*** (found in most hair conditioners, serve as antistatic agents), can then become attached to the hair via electrostatic interactions. Once attached, these compounds have several good effects. Their long hydrocarbon backbone helps to lubricate the surface of each hair follicle, reducing the sensation of roughness and assisting in combing.

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APPENDIX 4

Module 3

Chemical Reactions: Energy, Rates and Equilibrium among Native Americans

M. A. Fosu and Dr. T. Gupta

Transformation of a substance to another occurs during chemical reactions. The process leading to the chemical transformation or change of one set of chemical substance to another occurring at a characteristic reaction rate at a given temperature and chemical concentration is termed as chemical reaction[1]. This encompasses transformation that involve the position of electrons in the forming and breaking of chemical bonds between atoms resulting in no change to the nuclei. The whole activity undergoes chemical change yielding one or more products. Their properties are usually different from the reactant. Reaction proceeding in the forward direction to achieve equilibrium is termed as spontaneous reaction. It requires no input of free energy. For every non-spontaneous reaction, there is an input of free energy for the reaction to proceed. Every chemical equation is used graphically to illustrate chemical or structural formulas of reactants on the left and those of products on the right. Both are separated by an arrow ( ), indicating direction and type of reaction. All equations are balanced according to stoichiometry[1]. Stoichiometry measures the quantitative relationship between the reactant and the product present in a chemical reaction.

Types of Chemical Reactions

Several types of chemical reactions occur based on what occurs when going from reactants to products.

Combination chemical reactions

In combination chemical reactions, two or more products form one product. Examples include.

1. Formation of sodium chloride (NaCl) from sodium metal and chlorine gas

$$2Na_{(s)} + Cl_{2(g)} \xrightarrow{\text{temperature}} 2NaCl_{\ (s)} \qquad \text{(eq1)}$$

2. Burning of coal (carbon) to produce carbon dioxide

$$C_{(s)} + O_{2(g)} \xrightarrow{\text{temperature}} CO_{2(g)} \qquad \text{(eq 2)}$$

Decomposition Chemical Reactions

Decomposition occurs when a single compound breaks down into two or more simpler compounds or elements. Examples are.

1. Decomposition of water into hydrogen and oxygen gas

$$2H_2O_{(l)} \xrightarrow{\text{temperature}} 2H_{2(g)} + O_{2(g)} \qquad \text{(eq 3)}$$

2. Decomposition of hydrogen peroxide to form oxygen gas and water

$$2H_2O_{2(l)} \xrightarrow{\text{temperature}} 2H_2O_{(l)} + O_{2(g)} \qquad \text{(eq 4)}$$

Single Replacement Chemical Reactions

In these reactions, more active element displaces another less active element from a compound. Example includes.

1. Displacement of copper metal by zinc when zinc metal piece is placed into a copper (II) Sulfate solution

$$Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)} \quad \text{(eq 5)}$$

Double Replacement Chemical Reactions

These are also termed metathesis or exchange reactions. In double displacement chemical reaction, two species are displaced leading to the formation of either a precipitate or neutral product (salt or water) via neutralization reaction. Example includes.

1. Reaction between potassium chloride and silver nitrate

$$KCl_{(aq)} + AgNO_{3(aq)} \longrightarrow AgCl_{(s)} + KNO_{3(aq)} \quad \text{(eq 6)}$$

Precipitation Chemical Reactions

This is the reaction which results in the formation of an insoluble solid in a solution. Example includes.

1. Mixing of potassium chloride and Silver Nitrate, resulting in the formation of a white insoluble solid Silver Chloride

$$KCl_{(aq)} + AgNO_{3(aq)} \longrightarrow AgCl_{(s)\ (precipitate)} + KNO_{3(aq)} \quad \text{(eq 7)}$$

Neutralization Reactions

They occur between an acid and a base leading to the formation of water. Example includes.

1. Reaction between sulfuric acid and sodium hydroxide

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} \quad \text{(eq 8)}$$

Redox Reactions

These reactions involve transfer of electrons between two species. An oxidation-reduction reaction is any chemical reaction in which the oxidation number of an atom, a molecule, or an ion changes by gaining or losing an electron. Examples include.

1. Reaction between zinc metal and cupper (II) sulfate solution

$$Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)} \quad \text{(eq 9)}$$

2. Burning of coal (carbon) to produce carbon dioxide

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \text{(eq 10)}$$

3. Formation of sodium chloride (NaCl) from sodium metal and chlorine gas

$$2Na_{(s)} + Cl_{2(g)} \longrightarrow 2NaCl_{(s)} \quad \text{(eq 11)}$$

Combustion Reactions

Chemical reactions cannot be explained without introduction to the combustion reactions. Reactions such as combustion of fire, and the reduction of ores to metals are known since ages. The last we will talk about and go deep is combustion reaction. Combustion occurs when a compound usually the one containing carbon, combines with the oxygen gas in the air. Commonly, this is called burning, and heat is the most useful product of most combustion reactions.

Implementing concept of equilibrium in Native American tribes' Annealing

Reactions can achieve a state of equilibrium. In a chemical reaction, chemical equilibrium is the state attained when both reactants and products are present in concentrations that does not change with time and properties of the system[2]. This is the state in which the rate of forward reaction equals the rate of backward reaction **(Figure S3).**

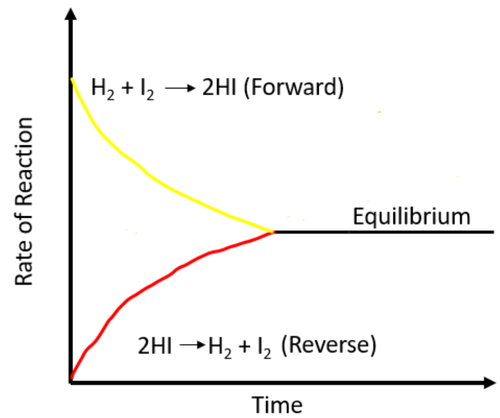

Figure S3. Diagram showing both forward and reverse reaction, and the chemical equilibrium

Metal annealing is a heat treatment that changes physical and at times chemical properties of a metal object. The Paleo-Indians of the Great Lakes Region of North America discovered this process that provided them versatility than that of previous metallurgical processes, such as cold hammering, bending or rolling, all of which cause metals to lose tensile strength and become more brittle[3]. This helps reduce the hardness and increases ductility of an object. The object is heated (measuring the kinetic energy of the particle) above its recrystallization temperature, retaining a certain suitable temperature for some time, and then cools down.

During annealing mechanism for many alloys, including carbon steels, atoms migrate or diffuse in the crystal lattice order within a solid material thereby reducing or decreasing the entropy. Both crystal grain size and phase composition (determining the material properties) are dependent on the alloys' heating and cooling rate. The object progresses towards its equilibrium state. Integration of heat increases the rate of diffusion by providing energy for bond breaking. Recrystallization is achieved by cooling. Material properties are determined at the crystal size and phase composition stage depending on the rate of heating and cooling of metals. This changes the structure of the metal. Annealing of metals help reduce the amount of process-initiating Gibbs free energy (ΔG stress relief to promote spontaneous process). Increase in temperature of annealing process may result in oxidation of the metal's surface[3]. Using endothermic gas (mixture of H_2, N_2 and CO) and forming gas as a special environment for annealing process are commonly used for "neutral" hardening and as a carrier gas for gas carburizing ($CO + H_2 = C + H_2O$) and carbonitriding [4].

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APPENDIX 5

Module 5

A study of solutions: From Native American Experience to Modern times

M A. Fosu & Dr. T. Gupta

Introduction to solutions

From module 1, we realized that matter could exist in the form of mixtures. What is the difference between homogenous and heterogenous mixtures? If you recall it has something to do with the consistency of compositions. In this chapter, we will consider a special type of homogenous mixtures, known as solutions. A solution is composed of two or more substances, in which the atoms and the molecules intermingle on both molecular and atomic scale. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent. Mixing of the solvent and the solute happens at a scale where the effects of chemical polarity are involved, resulting in interactions that are specific to solvation. The phase of the solvent is assumed by the solution when the solvent is the larger fraction of the mixture, as is commonly the case. The concentration of a solute in a solution is the mass of that solute expressed as a percentage of the mass of the whole solution[1] (mass percent).

There are several common examples of solutions. They include the gasoline we put in our car, the air we breathe, our daily coffee, saltwater, carbonated beverages etc. As you go through this module, keep in mind the great number of solutions are surrounding you at every moment, including those that exist in your own system[1]. Solution have several characteristics. The particles of solute in a solution cannot be seen with the naked eye, they are very stable, composed of only one phase, and do not allow beams of light to scatter them. Their particles cannot easily be separated by mechanism such as filtration.

Types of Solutions and Solubility

Solution can be made up of several combinations. Solution can be made up of a solid and liquid (example is with the sugar and water, gas and liquid (example is club soda), solid and solid (example copper and zinc forming a brass), gas and gas (like air which is mainly of oxygen and nitrogen), and lastly, liquid and liquid (example is ethanol and water to form vodka) **(See Table 1.0)**. For aqueous solutions, water serves as the solvent, and a liquid, solid, or gas serves as the solute.

Colligative property application among the native Americans

Colligative property is applied among the native Americans during the use of dogbane (a perennial plant). Native Americans used dogbane in treating dropsy, a condition characterized by an accumulation of fluid in body tissue. This fluid accumulation is caused by renal and cardiac failure. The use of dogbane in treating fluid accumulation reflects on the principle of osmotic pressure of a solution as the minimum amount of pressure required to prevent water from flowing into the system across a semipermeable membrane. The principle of osmotic pressure explains how readily water can enter the solution via osmosis, across a semi permeable membrane. The American Indians were the first to use dogbane to treat edema stemming from renal and cardiac failure. The Potawatomi of the Northeast boiled the green fruit of dogbane to produce an extract or tea to treat these problems, and to reduce high blood pressure[2]. When extract is consumed orally, it rids the body of excess fluid in so many ways. The concentrated dogbane extract exerts an osmotic pressure that stops the process of osmosis (the fluid accumulation due to renal or cardiac dysfunction). It acts like digitalis by strengthening the function of the heart and regulating its rhythm. Dogbane is also effective in reducing excess body fluid by causing expectoration (the ejection of mucous from the lungs), diaphoresis (profuse sweating), emesis (vomiting), and catharsis (emptying of the digestive system)[2].

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APPENDIX 6

Module 5

Acid-Base Chemistry from a Cultural Standpoint

M A. Fosu & Dr. T. Gupta

The reactions of Acids and bases are used extensively in everyday life and are central to the functioning of the human body. Acids and bases contribute to industrial needs and the environment. Therefore, it is essential that the degree of acidity in these situations is continually monitored. Concept of acidity originally came from the ancient Greeks who by definition described “sour tasting” substances as Oxein. This later mutated into the Latin work for vinegar. Currently, it is known as “Acid”. Acidic substances taste sour, change the color of blue litmus paper to red and corrode metals[1].

For bases, they were defined by their ability to counteract acids-and thus followed acids in their chemical characterization. Alkalinity was derived from an Arabic root word associated with “roasting” because of the fact that the first bases were characterized from soap-making substances derived from roasting ashes and treating them with water and slaked lime (a caustic substance produced by heating limestone)[1]. Investigating the qualitative and quantitative properties of acids and bases may lead to a better understanding of the strength of an acid and base as measured by pH and also visible changes in pH that can be attributed to the use of color indicators.

Historical Definition of Acids and Bases

An acid–base reaction occurs between an acid and a base, and can be used to determine pH. Acid-base theories serve as a basis of the reaction mechanisms or interaction between acidic ad basic substances. When a brilliant French chemist Antoine Lavoisier (1743 -1794) attempted to group elements and understand the nature of heat, it also led to a systematic study of acids and bases. At that time, chemists began to define bases as substances that could neutralize acids to form water and a salt. In 1776, influenced by studies into the properties of gases, Lavoisier tried to isolate the compound in acids responsible for their unique properties. He (somewhat) incorrectly proposed that a substance called oxygen was responsible, such observations even though incorrectly or incomplete led to further studies in this area. Lavoisier observations pointed to presence of oxygen . The British scientist, Humphrey Davy (1778-1829), being responsible for acidic behavior, tested the theories of Lavoisier and discovered that oxygen was not the element responsible for the properties of acids but, many acids did not contain oxygen, so he proposed that something else must be responsible.

In Germany, Justus Frieherr von Liebig (1803-1873), another innovative chemist, instead isolated hydrogen as the element responsible, reasoning that it was the only element common to all acids. The Swedish chemist, Svante Arrhenius (1859-1927), was the next chemist to study acids and bases, proposing that acids and bases gained their properties because of the action of ions in the solution. Arrhenius stated that acids are simply substances that add hydrogen cations H^+ to water.

For example, Hydrochloric acid, HCl, adds H^+ and Cl^- ions to water. Conversely, alkalis add hydroxyl ions, OH^-. For example, sodium hydroxide, adds Na^+ and OH^- to the water. The reason that acids and bases neutralize each other out is because the H^+ and OH^- ions react to form water, leaving salts behind.

$$HCl + NaOH \longrightarrow NaCl \text{ (Table Salt)} + H_20$$

This definition of acids and bases seemed to apply to several compounds at that time. These testing compounds opened up a realm of possibility and chemists could work out which proportion of acids and bases would neutralize each other, allowing them to roughly compare the relative strength of acids and bases.

Heartburn is a painful sensation in the esophagus. This is caused by hydrochloric acid (which the stomach excretes to kill microorganisms and to activate enzymes to break down food) backup out of the stomach and into the esophagus, producing H^+ ions resulting in a burning sensation. Saliva contains bicarbonate ions (HCO_3^-) which acts as a base and neutralizes the acid. Baking soda reacts with acid molecules in the air to freshen refrigerators, used as a cattle feed supplement, in particular as a buffer for the rumen (primary site for microbial fermentation of ingested food). Small amount of sodium bicarbonate has been shown to be useful as a supplement for athletes in speed-based events, such as middle-distance running, lasting from about one to seven minutes. At 158° F (70° C) sodium bicarbonate breaks down into sodium carbonate, water vapor, and carbon dioxide gas, and thus can be used to make foamed candy by adding it to a very hot syrup. For the same reason, it can be used as a fire suppressor in fire extinguishers, or simply by putting a box of it on a kitchen fire.

- Reaction of sodium bicarbonate and an acid produces a salt and carbonic acid, which readily decomposes to carbon dioxide and water as shown below:

$$NaHCO_3 + HCl \rightarrow NaCl + H_2CO_3$$

$$H_2CO_3 \rightarrow H_2O + CO_2(g)$$

- Sodium bicarbonate also reacts with acetic acid (found in vinegar), producing sodium acetate, water, and carbon dioxide:

$$NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2(g)$$

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APPENDIX 7

MOSART TEST

CHEMISTRY TEST (Sample Questions)

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

1. The chemical reaction of photosynthesis naturally occurs in the presence of sunlight because the light: a. is one of the reactants.

b. helps oxygen to "see" carbon dioxide.

c. vaporizes water.

d. provides the energy to start the reaction.

e. brings the oxygen into the plant.

2. What general shape will CCl_4 most likely have?

a. Linear

b. Trigonal planar (triangle)

c. Tetrahedral

d. Trigonal pyramid

e. V-shaped

3. Of the following, which are linked to chemical reactions in humans?

a. Digestion

b. Taste

c. Vision

d. a and b

e. a, b, and c

4. What is in between the electrons and nucleus of an atom?

a. Nothing

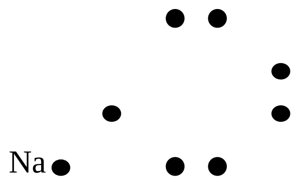
b. Air

c. Water vapor

d. Smaller atoms

e. No one knows.

5. Chemists say that when these two atoms react the Na outer electron is:



a. shared.

b. transferred.

c. combined.

d. destroyed.

e. subtracted.

GO TO QUESTION 6 >>

6. The charge in a nucleus of an atom is:

a. neutral.

b. negative.

c. positive.

d. continuously changing.

e. not possible to determine.

7. The rightmost column of the Periodic Table includes the noble gases, all of which:

a. are lighter than air.

b. are never liquid or solid at any temperature.

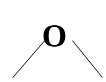
c. are found only in Earth’s atmosphere.

d. are missing one electron in their outer orbital.

e. have filled electron shells.

8. Which of the compounds below is most likely to have a dipole moment (be polar)?

1. 2. 3.



H — F **O = C = O** **H** **H**

a. 1

b. 2

c. 3

d. 1 and 3

e. 1, 2 and 3

9. If you were to hammer some gold into a thin sheet, the atoms:

a. would each flatten out.

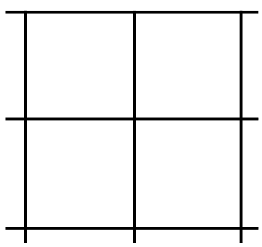
b. weigh less.

c. are pushed closer together.

d. are unchanged.

e. None of the above.

10. A portion of the Periodic Table is shown below.



Which element(s) has exactly one more outermost electron than element N? a. Only O.

b. Only P.

c. O and S.

d. All of the other elements have exactly one more outermost electron than element N.

e. None of the other elements has exactly one more outermost electron than element N.

APPENDIX 8

California Standard TEST (Sample Questions)

A weather balloon with a 2-meter diameter at ambient temperature holds 525 grams of helium. What type of electronic probe could be used to determine the pressure inside the balloon?

A barometric

B thermometric

C calorimetric

D spectrophotometric

CSC10177

2 Which would be *most* appropriate for collecting data during a neutralization reaction?

A a pH probe

B a statistics program

C a thermometer

D a graphing program

CSC20124

3 A scientist observed changes in the gas pressure of one mole of a gas in a sealed chamber with a fixed volume. To identify the source of the changes, the scientist should check for variations in the

A air pressure outside the chamber.

B molecular formula of the gas.

C temperature of the chamber.

D isotopes of the gas.

CSC10120

4 Electrical fires cannot be safely put out by dousing them with water. However, fire extinguishers that spray solid carbon dioxide on the fire work very effectively. This method works because carbon dioxide

A displaces the oxygen.

B renders the fire's fuel non-flammable. **C** forms water vapor.

D blows the fire out with strong wind currents.

CSC00005

5 In order to advance to the level of a theory, a hypothesis should be

A obviously accepted by most people.

B a fully functional experiment.

C in alignment with past theories. **D** repeatedly confirmed by experimentation.

CSC00144

6 Matter is made of atoms that have positive centers of neutrons and protons surrounded by a cloud of negatively charged electrons. This statement is

A a theory.

B a hypothesis.

C an inference.

D an observation.

CSC20129

7 When a metal is heated in a flame, the flame has a distinctive color. This information was eventually extended to the study of stars because

A the color spectra of stars indicate which elements are present.

B a red shift in star color indicates stars are moving away.

C star color indicates absolute distance.

D it allows the observer to determine the size of stars.

APPENDIX 9

Course Exams (1-4)

Exam 1(example of sample questions for exam 1)

1. Calculate the density of cyclohexane if a 50.0 g sample has a volume of 64.3 milliliters.
   a) 0114.3 g/mL

b) 14.3 g/mL

c) 1.29 g/mL

d) 0.778 g/mL

e) 0.322 g/mL

2. Which of the following is a physical change?

a) the rusting of iron

b) the condensation of water vapor

c) the baking of a potato

d) the explosion of nitroglycerin

e) all of the above

3. Which term **does not** describe a process that is responsible for the conversion between the states of matter or phase changes?

a) condensation

b) evaporation

c) freezing

d) melting

e) mixing

4. Which particle has a mass approximately equal to the mass of a proton?

a) Atom

b) electron

c) neutron

d) nucleus

e) anion

5. How many quarts are contained in 450 mL?

a) 0.426 quart

b) 2.10 quarts

c) 426 quarts

d) 475 quarts

e) 0.475 quarts

6. What temperature is 325 K on the Celsius scale?

a) 344 ˚C

b) 598 ˚C

c) 52˚C

d) 40 ˚C

e) 126 ˚C

7. Which of the following is a **physical** property of aspirin?

a) Aspirin can moderate some heart disorders when ingested.

b) Aspirin decomposes in an unsealed bottle.

c) Aspirin yields carbon dioxide and water vapor when burned.

d) Aspirin can be pressed into tablets when mixed with cornstarch.

e) Aspirin reacts with water to produce salicylic acid and acetic acid

8. 1-butanethiol, one of the compounds giving skunks their distinctive odor, freezes at -115.7°C and boils at 98.5°C. What is its phase at 37°C, the normal body temperature of humans? a) Solid

b) Liquid

c) Gaseous

d) A mixture of a solid and liquid

e) A mixture of a liquid and gas

9. Which element is most likely to have chemical properties similar to those of bromine (atomic number 35)?

a) Sulfur

b) Selenium

c) Krypton

d) Tellurium

e) Iodine

10. An atom with Z = 26 and A = 58 contains ________ protons and ________ neutrons? a) 26; 58

b) 58; 26

c) 26; 32

d) 32; 26

e) 26; 84

f)

Exam 2 (example of sample questions for exam 2)

____

1. What is the name of NO_3^- ion?

a) Nitrite ion

b) Nitride ion

c) Nitrite ion

d) Nitrate ion

e) Nitrogen oxide ion

2. The formula for sulfur hexabromide is:

a) SF_6

b) SBr_6

c) S_6Br

d) $SiBr_6$

e) Si_6Br

3. A molecule in which the central atom forms three single bonds and has one lone pair is said to have a ________. a) Bent

b) Pyramidal

c) Linear

d) Tetrahedral

e) Trigonal planar

4. The water molecule has a ________ geometry because its central atom has ________ bonds and ________ lone pairs of electrons. a) bent; two; two

b) linear; two; two

c) pyramidal; three; one

d) tetrahedral; four; zero

e) planar triangular; three; one

5. Which element listed is the **most** electronegative?

a) Aluminum
b) Bromine
c) Chlorine
d) Iodine
e) Sodium

6. A bond where the electrons are shared unequally is called a(an) _________ bond.

a) Non-polar bond
b) Covalent bond
c) Ionic bond
d) Polar covalent bond
e) Hydrogen bond

7. What is the systematic name of ICl_3?

a) iodine chloride
b) iodine(III) chloride
c) triiodine chloride
d) tri(iodine chloride)
e) iodine trichloride

8. What is the formula of the ammonium ion?

a) Am^-
b) Am^+
c) NH_4^+
d) NH_3^+

e) NH_2^-

9. A chemical bond formed between two identical atoms is a(an) ________ bond. a) atomic

b) covalent
c) hydrogen
d) ionic
e) polar

10. Which group contains only elements which normally exist as diatomic molecules?

a) nitrogen; sulfur, bromine
b) helium; neon, argon
c) nitrogen; oxygen, fluorine
d) hydrogen; lithium, sodium
e) oxygen; phosphorus, germanium

Exam 3 (example of sample questions for exam 3)

1. How many molecules are present in 4.25 moles of CCl4?
a) 9.26×10^{24} molecules
b) 2.56×10^{24} molecules
c) 653.69 molecules
d) 153.81 molecules

e) 3.69×10^{-23} molecules

2. 50.0 g of Cl_2 contains ________ mol Cl_2.

a) 0.705

b) 50.0

c) 1775

d) 1.41

e) 4.24×10^{23}

3. Acid rain forms in the upper atmosphere by the reaction of sulfur trioxide with water forming sulfuric acid. Calculate the mass in grams of 5.65×10^{21} molecules of SO_3. The molar mass of SO_3 = 80.066 g/mole. a) 2.72×10^{47} g

b) 1.17×10^{-4} g

c) 0.0751 g

d) 1.17 g

e) 0.751 g

4. The Haber process is used to make ammonia, which is an important source of nitrogen that can be metabolized by plants. Using the equation below, determine how many moles of ammonia will be formed from 8.55 mole of nitrogen. $N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$ a) 17.1 mol

b) 4.28 mol

c) 0.240 mol

d) 5.7 mol

e) 12.8 mol

5. The following equation represents the formation of nitrogen dioxide, a major component of smog. 2 NO + O2 → 2 NO2

If 0.68 mole of NO is reacted with 0.79 mole of O2 to produce NO2, the limiting reactant is:

a) Both NO and O2
b) O2
c) NO2
d) NO
e) None of above is limiting reagent.

6. Which of the following contains kinetic energy?
a) bicycle at the top of a hill
b) ball laying on the ground
c) a battery
d) a piece of chocolate
e) A stream downhill

7. A process or reaction which absorbs heat from the surroundings is said to be: a) conservative.
b) endothermic.
c) exothermic.
d) isothermal.
e) exergonic.

8. Consider the reaction shown: $CaCO_3(s) + 288.62\ kcal \rightarrow CaO(s) + CO_2$ We can say that this reaction is ________ and that the sign of ΔH is ________. a) endothermic; positive
b) exothermic; positive
c) endothermic; negative
d) exothermic; negative

e) exothermic; neither positive nor negative

9. Based on the comparison of bond energies given for each of the following which is the most stable bond?

a) N=O	607 kJ/Mol
b) O=O	498 kJ/mol
c) C=O	745 kJ/mol
d) C=C	614 kJ/mol
e) C≡C	839 kJ/mol

10. A reaction that is spontaneous can be described as

a) Proceeding in both the forward and reverse directions.

b) Having the same rate in both the forward and reverse directions.

c) Releasing heat to the surroundings.

d) Proceeding without external influence once it has begun.

e) Increasing in disorder.

Exam 4 (example of sample questions for exam 4)

1. Which one of the following would act like a strong electrolyte in an aqueous solution?

a) KNO_3

b) CH_3OH

c) CCl_4

d) NH3

e) CH_4

2. Considering 1.0 M solutions of each substance, which contains the largest concentration of ions? a) K_2SO_4

b) $FeCl_3$

c) NaOH

d) LiCl

e) KCl

3. Which of the following is miscible with CH_3CH_2OH?

a) $CH_3CH_2CH_3$

b) CH_3OH

c) CCl_4

d) CH_3CH_3

e) CBr_4

4. In our stomach, gastric juice that is about 0.1 *M* in HCl aids in digestion. How many milliliters of gastric juice will react completely with an antacid tablet that contains 500 mg of magnesium hydroxide? The balanced equation for this reaction is: 2 $HCl(aq) + Mg(OH)_2(aq)$ à $MgCl_2(aq) + 2\ H_2O(l)$

a) 200 mL

b) 18 mL

c) 172 mL

d) 1700 mL

e) 0.0017 mL

5. Aqueous ammonia is commercially available at a concentration of 16.0 *M*. How much of the concentrated solution would you use to prepare 550.0 mL of a 1.90 *M* solution?

a) 100 mL

b) 550 mL

c) 80 mL

d) 70 mL

e) 65.3 mL

6. What would be the new pressure if a 400 mL gas sample at 380 mm Hg is expanded to 800 mL with no change in temperature? a) 190 mm Hg

b) 380 mm Hg

c) 570 mm Hg

d) 760 mm Hg

e) 950 mm Hg

7. A 6.3 L sample of helium gas stored at 25 °C and 1.0 atm pressure is transferred to a 2.0 L tank and maintained at a pressure of 2.8 atm. What temperature is needed to maintain this pressure? a) 265 K

b) 300 K

c) 400 K

d) 600 K

e) 700 K

8. How many moles of air are in the lungs of an average person with a total lung capacity of 3.8 L? Assume that the person is at 1.0 atm pressure and has a normal body temperature of 37 °C? a) 0.011 mole

b) 0.15 moles

c) 1.15 moles

d) 1.5 moles

e) 0.0015 moles

9. Which of the following can serve as the solvent in a solution? a) a gas

b) a liquid

c) a solid

d) a mixture of two liquids

e) All of the above

10. The maximum allowable concentration of chloroform, $CHCl_3$, in drinking water is 100 ppb. What is the maximum amount (in grams) of chloroform allowed in a glass containing 400 g (400 mL) of water? a) 4 $\times 10^{-5}$ grams

b) 0.04 grams

APPENDIX 10

MODULE QUIZZES (Sample Questions)

Questions on Matter and Measurements (Module 1)

1. A consistent explanation of known observation is called

A.) An experiment

B.) A hypothesis

C.) A prediction

D.) A theory

2. The scientific procedure undertaken to help test a hypothesis is termed as

A.) A prediction

B.) An experiment

C.) A theory

D.) An observation

3. Salicin, a complex compound used by the Indigenous people in treating headaches and fever. Which of the following compound is the chemical formula of Salicin?

A.) $C_7H_6O_3$

B.) $C_{13}H_{18}O_7$

C.) $C_{22}H_{34}O_7$

D.) $C_{12}H_{22}O_{11}$

4. A student weighed 6000.µg of magnesium in the lab. This is the same mass as
A.) 6.000×10^{-6} g.

B.) 6.000×10^{-3}kg.

C.) 6.000×10^{-3}mg.

D.) 6.000×10^{6}ng.

5. The use of an openwork basket by the indigenous women to sift out stems and leaves from seeds followed the principle of ………………… to maintain seeds.

A.) Making it less dense

B.) Making it more dense

C.) Increasing its volume

D.) Increasing the total mass of the mixture

Questions on Chemical Bonding (Module 2)

1. Covalent bonding is a

a.) Loss of electrons
b.) Gain of electrons
c.) Transfer of electrons
d.) Sharing of electrons

2. The compound K_2CO_3 used during activation of charcoal contains

a.) Nonpolar covalent bonds
b.) Ionic bonds
c.) Polar covalent bonds, with partial negative charges on the K^+
d.) Polar covalent bonds, with partial negative charge on the CO_3^{2-}

3. Which group of elements are found as diatomic molecules?

a.) Alkaline earth metals

b.) Halogens

c.) Noble gases

d.) Alkaline metals

4. The outer shell electron associated within the atom is termed as the?

a.) Valence electron

b.) Orbital

c.) Inner electrons

d.) Free electrons

5. During electroplating, the corrosive liquid ($CuSO_4$) produced by the Moche undergoes?

a.) Covalent Bonding

b.) Polar covalent bonding

c.) Ionic boding

d.) Nonpolar Covalent bonding

Questions on Chemical Reactions (Module 3)

1. In a thermal decomposition reaction according to the equation:

$CaCO_3 \rightarrow CaO + CO_2$

The resulting reaction had a lower temperature before the breaking of bonds or chemically decomposed.

What are the signs of ΔH^0 and ΔS^0 for this reaction?

A.) ΔH^0 is negative and ΔS^0 is positive

B.) ΔH^0 is negative and ΔS^0 is negative

C.) ΔH^0 is positive and ΔS^0 is negative

D.) ΔH^0 is positive and ΔS^0 is positive

2. In burning of trees and shrubs during *milpa*

A.) Both the energy and the entropy of the system and surrounding decrease

B.) Energy is conserved and the entropy of the system and surrounding increases

C.) The energy of the system and the surroundings decreases, and the entropy of the system and surroundings increases.

D.) An endothermic reaction

3. For annealing process by the indigenous people, $\Delta G = \Delta H$ at a given temperature and pressure. Therefore,

A.) $\Delta S = \Delta G/T$

B.) ΔS is Zero

C.) ΔS is negative if ΔH is positive and negative is ΔH is negative

D.) ΔS is positive if ΔH is positive and negative is ΔH is negative

4. Freeze-drying technique for preserving their surplus vegetables and potato crops by arranging them on the ground and leaving them overnight to freeze was

A.) Both the energy and the entropy of the system and surrounding decrease

B.) Energy is conserved and the entropy of the system and surrounding increases

C.) The energy of the system and the surroundings decreases, and the entropy of the system and surroundings increases.

D.) An endothermic reaction

5. A chemical reaction that involves the transfer of electrons between two species is termed?

A.) Precipitation chemical reaction

B.) Combustion chemical reaction

C.) Redox chemical reaction

D.) Neutralization chemical reaction

Questions on Solutions (Module 4)

1. In most liquid solutions, the component present in the larger amount is called the

a.) Solute

B.) Solvent

C.) Dispersed medium

D.) Saturated solution

2. Brass is an example of a .... solution

A.) Liquid/liquid solution

B.) Solid/liquid solution

C.) Solid/solid solution

D.) Gas/solid solution

3.) For the process of dissolving a solid in a liquid, which of the following statements is true?

A.) $\Delta H_{Solution}$ is always negative and $\Delta S_{Solution}$ is usually positive

B.) $\Delta H_{Solution}$ is always positive and $\Delta S_{Solution}$ is usually negative

C.) $\Delta H_{Solution}$ is either positive or negative and $\Delta S_{Solution}$ is usually positive

D.) $\Delta H_{Solution}$ is either positive or negative and $\Delta S_{Solution}$ is usually negative

4.) Which of the following does not affect the solubility of the solute in a given solvent?

A.) Polarity of a solvent

B.) Polarity of solute

C.) Rate of stirring

D.) Temperature of the solvent and solute

5. Two aqueous solutions, A and B, are separated by a semi permeable membrane. The osmotic pressure of solution A immediately begins to decrease. Which of the following statements is true?

A.) Solvent molecules are moving from solution B into solution A

B.) The initial osmotic pressure of solution B is greater than that of solution A

C.) The solvent molecules are moving from the solutions of higher osmotic pressure to that of lower osmotic pressure.

D.) Both B and C are true statements

Questions on Acids and Bases (Module 5)

1. Which one of the following species acts as an acid in water?

A.) CH_3NH_2

B.) C_6H_6

C.) NH_4^+

D.) NaH

2. The following reaction shows the traditional vinegar preparation pathway.

A.) $CH_2CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$

B.) $CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$

C.) $CH_3CH_2CO_2H + Ca(OH)_2 \rightarrow (CH_3CH_2CO_2)_2Ca + H_2O$

D.) $HBr + NaOH \rightarrow NaBr + H_2O$

Following substances are categorize as acids except.

Lemon

Batteries

Vinegar

Baking soda

What is the strongest acid among the following?

H_2SO_3

H_2SO_4

H_2SeO_3

H_2SeO_4

…………………. was an alkaline solution used by Native Americans to remove hulls from corn?

Sodium hydroxide

Magnesium hydroxide

Vinegar

Wood-ash

APPENDIX 11

STUDENTS DISCUSSION PROMPTS

Discussion Prompts (Module 1): Keywords used for the discussion of modules

1. scientific method
2. scientific method outside the classroom – steps used.
3. Sequential use of steps or flexible
4. measurements and life
5. Apply density in practical ways.
6. states of matter
7. Native American practices and modern life

Discussion Prompts (Module 2)

1. ionic compounds?
2. periodic table and the number of bonds in ionic compounds.
3. ionic compounds and as acids, bases, and salts
4. ionic compounds and salt formation.
5. salt for sustainability and iodine consumption; activated charcoal ; ionic bonding for electroplating; hair conditioner.

Discussion Prompts (Module 3)

1. types of chemical reactions, energy, reaction rates and chemical equilibrium

2. endothermic and exothermic processes

3. entropy, enthalpy, spontaneous and non-spontaneous processes

4. native Americans

5. everyday life

Discussion Prompts (Module 4)

1. Solutions

2. entropy - intermolecular forces - solubility.

3. Native Americans - colligative property – uses

4. Water-soluble vitamins dissolve easily in our body fluids and easily eradicated during metabolism. Due to this, it is recommended that water-soluble vitamins be consume more often. For fat-soluble vitamins, they can be dangerous to our body system if much is accumulated because of overconsumption of these vitamins. For vitamin C chemical structure shown below (Figure 8), the four –OH bonds in its structure make it highly polar, allowing it to form hydrogen bond with water. This makes vitamin C a water-soluble vitamin.

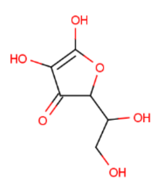
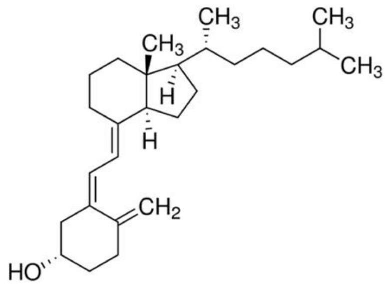


Figure 8. Chemical structure of Vitamin C

vitamin structures below - group as water-soluble or fat-soluble vitamins.



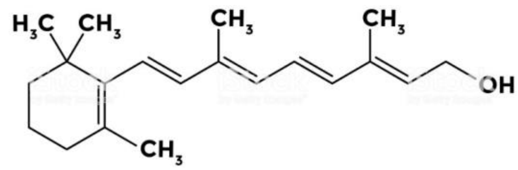


Figure 10. Vitamin A structure

Figure 9. Structure of Vitamin D3

Discussion Prompts (Module 5)

Acids - lactic acid, and citric acid; Bases Sodium hydroxide and Magnesium hydroxide.

culture – uses – Native Americans-Life

1. acid-base reaction:

   $H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

2. Combustion - impurities - fossil fuels - produce SO_2. Nitrogen - air reacts form NO_2. SO_2 and NO_2 react with water - form sulfuric acid and nitric acid – ACID RAIN - Problem-Solution.

   $2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$

   $NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$

3. Ulcer is a lesion on the wall of the stomach or small intestine - thick layer of mucus lines the stomach wall - protects it from the stomach acid and gastric juices - mucous layer is damaged – ULCER happens – Dessert that will cause irritation.

APPENDIX 12

Interview Protocol for CRCE

There are four parts to this interview. The main objective to this interview is to understand your experience with the modules and how it impacted your overall understanding of concepts introduced in this course. **Part I** includes questions about your background in science and your preparation towards studying chemistry. **Part II** addresses questions about resources in curriculum to better understand the tools that helps in learning chemistry. **Part III** includes questions about your traditional practices and your knowledge in chemistry. **Part IV** includes what you think can contribute to the learning of chemistry using cultural modern approach.

If you want to share your experience as example to explain how you understood the concepts through the modules or any example provided by a colleague during the discussion on D2L, you do not need to call them by their names. if you do, we will exclude their names from our writings.

Kindly note that everything you say is highly confidential and will remain in the four corners of this room. No information you provide will go to any university office or committee.

Part 1: Background and Preparation

1. Can you describe your experiences learning science as a student?
2. What was the initial feeling learning chemistry?

a. Any regret?

3. How did your Chemistry class and lab go?

a. Which topic(s) went well?

b. Which topics were boring? Why?

c. Do you connect that to your every-day life?

4. How did you see learning chemistry concepts to be like?

Part II: Resources in curriculum

5. In your opinion, what curriculum resources do you find useful for learning chemistry (textbooks, lectures, notes, videos, modules etc.)

6. What ways are these curricular resources beneficial for learning chemistry?

7. In your opinion what are some problems with the resources you use for learning chemistry? a. How can it be made better?

8. What are some things you do to make sure that you are learning and understanding the material?

Part III: Traditional practices and knowledge of chemistry

9. What was your knowledge of cultural practices and traditional applications of chemistry before experiencing these modules?

10. What do you think about the curriculum and instruction of chemistry from a cultural point of view?

11. What are some traditional practices in which chemistry is used or did you know of some traditional and cultural aspects in which chemistry finds application before module introduction?

12. What kind of native American's practices from the modules do you think were unique and got you interested in the concepts?
13. What are the advantages of learning about chemistry from a cultural standpoint?
14. What are the drawbacks or disadvantages of learning about chemistry using the modules?
15. On a scale of 1-5, how will you rate the difficulty of understanding the modules concept?
16. Were there certain examples from the modules that helped you learn better or made it harder to learn chemistry?
17. What are your suggestions to improve the modules you have experienced? What ways can the modules be improved to help understand chemistry better?

Part IV: Closing

18. Is there anything you would like to share about the module that I may have overlooked?
19. Overall, after going through this class and modules, what do you enjoy about studying chemistry via cultural and every-day standpoints?

Demographics

1. Name:
2. Gender:
3. Ethnicity:
4. Major:

APPENDIX 13

Students' Adaptive Learning Engagement in Science (SALES) questionnaire

Directions for Students

Here are some statements about you as a student in this class. Please read each statement carefully. Circle the number that best describes what you think about these statements.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

For each statement, draw a circle around

1 if you *Strongly disagree* with the statement

2 if you *Disagree* with the statement

3 if you *Are not sure* about the statement

4 if you *Agree* with the statement

5 if you *Strongly agree* with the statement

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Learning goal orientation	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
In this science class …					
1.One of my goals is to learn as much as I can.	1	2	3	4	5
2.One of my goals is to learn new science contents.	1	2	3	4	5
3.One of my goals is to master new science skills.	1	2	3	4	5
4.It is important that I understand my work.	1	2	3	4	5
5.It is important for me to learn the science content that is taught.	1	2	3	4	5
6.It is important to me that I improve my science skills.	1	2	3	4	5
7.It is important that I understand what is being taught to me.	1	2	3	4	5
8.Understanding science ideas is important to me.	1	2	3	4	5

Task value	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
In this science class …					
9.What I learn can be used in my daily life.	1	2	3	4	5
10.What I learn is interesting.	1	2	3	4	5
11.What I learn is useful for me to know.	1	2	3	4	5
12.What I learn is helpful to me.	1	2	3	4	5

13.What I learn is relevant to me.	1	2	3	4	5
14.What I learn is of practical value.	1	2	3	4	5
15.What I learn satisfies my curiosity.	1	2	3	4	5
16.What I learn encourages me to think.	1	2	3	4	5
Self-efficacy	Strongly disagree	Disagree	Not sure	Agree	SStrongly agree
In this science class …					
17.I can master the skills that are taught.	1	2	3	4	5
18.I can figure out how to do difficult work.	1	2	3	4	5
19.Even if the science work is hard, I can learn it.	1	2	3	4	5
20.I can complete difficult work if I try.	1	2	3	4	5
21.I will receive good grades.	1	2	3	4	5
22.I can learn the work we do.	1	2	3	4	5
23.I can understand the contents taught.	1	2	3	4	5
24.I am good at this subject.	1	2	3	4	5
Self-regulation	Strongly disagree	Disagree	Not sure	Agree	SStrongly agree
In this science class …					
25.Even when tasks are uninteresting, I keep working.	1	2	3	4	5
26.I work hard even if I do not like what I am doing.	1	2	3	4	5

27.I continue working even if there are better things to do.	1	2	3	4	5
28.I concentrate so that I will not miss important points.	1	2	3	4	5
29.I finish my work and assignments on time.	1	2	3	4	5
30.I do not give up even when the work is difficult.	1	2	3	4	5
31.I concentrate in class.	1	2	3	4	5
32.I keep working until I finish what I am supposed to do.	1	2	3	4	5

APPENDIX 14

Attitude Toward the Subject Chemistry Inventory

Survey

A list of opposing words appears below. Rate how well these words describe your feelings about **chemistry**. Think carefully and **try not to include** your feelings toward chemistry teachers or chemistry courses. For each line, choose a position between the two words that describes **exactly how you feel**. Mark that number here or on the standard answer sheet. The middle position is if you are undecided or have no feelings related to the terms on that line.

CHEMISTRY IS

1. easy |__1__|__2__|__3__|__4__|__5__|__6__|__7__| hard

   middle

2. worthless |__1__|__2__|__3__|__4__|__5__|__6__|__7__| beneficial

3. exciting |__1__|__2__|__3__|__4__|__5__|__6__|__7__| boring

4. complicated |__1__|__2__|__3__|__4__|__5__|__6__|__7__| simple

5. confusing |__1__|__2__|__3__|__4__|__5__|__6__|__7__| clear

6. good |__1__|__2__|__3__|__4__|__5__|__6__|__7__| bad

   middle

7. satisfying |__1__|__2__|__3__|__4__|__5__|__6__|__7__| frustrating

8. scary |__1__|__2__|__3__|__4__|__5__|__6__|__7__| fun

9. comprehensible|__1__|__2__|__3__|__4__|__5__|__6__|__7__|incomprehensible

10. challenging|__1__|__2__|__3__|__4__|__5__|__6__|__7__| not challenging

11. pleasant|__1__|__2__|__3__|__4__|__5__|__6__|__7__|unpleasant

middle

interesting |__1__|__2__|__3__|__4__|__5__|__6__|__7__| dull

13. disgusting |__1__|__2__|__3__|__4__|__5__|__6__|__7__| attractive

14. comfortable|__1__|__2__|__3__|__4__|__5__|__6__|__7__ uncomfortable

15. worthwhile |__1__|__2__|__3__|__4__|__5__|__6__|__7__| useless

16. work |__1__|__2__|__3__|__4__|__5__|__6__|__7__| play

middle

17. chaotic |__1__|__2__|__3__|__4__|__5__|__6__|__7__| organized

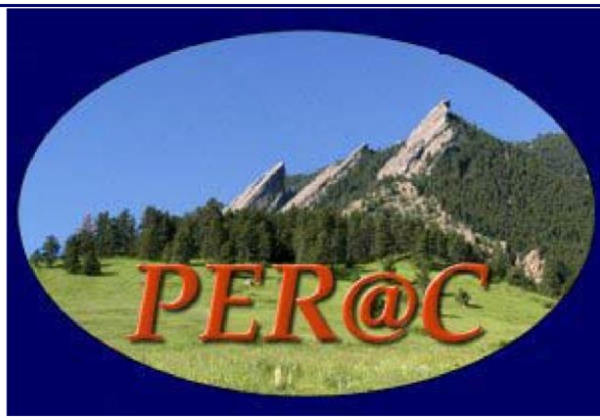
18. safe |__1__|__2__|__3__|__4__|__5__|__6__|__7__| dangerous

20. tense |__1__|__2__|__3__|__4__|__5__|__6__|__7__| relaxed

21. insecure |__1__|__2__|__3__|__4__|__5__|__6__|__7__| secure

APPENDIX 15

CLASS-Chem Survey



CLASS-Chemistry

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(Colorado Learning Attitudes about Science Survey)

Name: ______________________________ Last 6 digits of your Student ID #: _____________

Introduction

Here are a number of statements that may or may not describe your beliefs about learning chemistry. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey

1. A significant problem in learning chemistry is being able to memorize all the information I need to know.

Strongly Disagree	1 2 3 4 5	Strongly Agree

2. To understand a chemical reaction, I think about the interactions between atoms and molecules.

Strongly Disagree	1 2 3 4 5	Strongly Agree

3. When I am solving a chemistry problem, I try to decide what would be a reasonable value for the answer.

Strongly Disagree	1 2 3 4 5	Strongly Agree

4. I think about the chemistry I experience in everyday life.

Strongly Disagree	1 2 3 4 5	Strongly Agree

5. It is useful for me to do lots and lots of problems when learning chemistry.

Strongly Disagree	1 2 3 4 5	Strongly Agree

6. After I study a topic in chemistry and feel that I understand it, I have difficulty solving problems on the same topic.

Strongly Disagree	1 2 3 4 5	Strongly Agree

7. Knowledge in chemistry consists of many disconnected topics.

Strongly Disagree	1 2 3 4 5	Strongly Agree

8. As chemists learn more, most chemistry ideas we use today are likely to be proven wrong.

Strongly Disagree	1 2 3 4 5	Strongly Agree

9. When I solve a chemistry problem, I locate an equation that uses the variables given in the problem and plug in the values.

Strongly Disagree	1 2 3 4 5	Strongly Agree

10. I find that reading the text in detail is a good way for me to learn chemistry.

Strongly Disagree	1 2 3 4 5	Strongly Agree

11. I think about how the atoms are arranged in a molecule to help my understanding of its behavior in chemical reactions.

Strongly Disagree	1 2 3 4 5	Strongly Agree

12. If I have not memorized the chemical behavior needed to answer a question on an exam, there's nothing much I can do (legally!) to figure out the behavior.

Strongly Disagree	1 2 3 4 5	Strongly Agree

13. I am not satisfied until I understand why something works the way it does.

Strongly Disagree	1 2 3 4 5	Strongly Agree

14. I cannot learn chemistry if the teacher does not explain things well in class.

Strongly Disagree	1 2 3 4 5	Strongly Agree

15. I do not expect equations to help my understanding of the ideas in chemistry; they are just for doing calculations.

Strongly Disagree	1 2 3 4 5	Strongly Agree

16. I study chemistry to learn knowledge that will be useful in my life outside of school.

Strongly Disagree	1 2 3 4 5	Strongly Agree

17. I can usually make sense of how two chemicals react with one another.

Strongly Disagree	1 2 3 4 5	Strongly Agree

18. If I get stuck on a chemistry problem on my first try, I usually try to figure out a different way that works.

Strongly Disagree	1 2 3 4 5	Strongly Agree

19. Nearly everyone is capable of understanding chemistry if they work at it.

Strongly Disagree	1 2 3 4 5	Strongly Agree

20. Understanding chemistry basically means being able to recall something you've read or been shown.

Strongly Disagree	1 2 3 4 5	Strongly Agree

21. Why chemicals react the way they do does not usually make sense to me; I just memorize what happens.

Strongly Disagree	1 2 3 4 5	Strongly Agree

22. To understand chemistry I discuss it with friends and other students.

Strongly Disagree	1 2 3 4 5	Strongly Agree

23. I do not spend more than five minutes stuck on a chemistry problem before giving up or seeking help from someone else.

Strongly Agree

Strongly Disagree	1 2 3 4 5	Strongly Agree

24. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

Strongly Disagree	1 2 3 4 5	Strongly Agree

25. If I want to apply a method used for solving one chemistry problem to another problem, the problems must involve very similar situations.

26. In doing a chemistry problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

Strongly Disagree	1 2 3 4 5	Strongly Agree

27. In chemistry, it is important for me to make sense out of formulas before I can use them correctly.

Strongly Disagree	1 2 3 4 5	Strongly Agree

28. I enjoy solving chemistry problems.

Strongly Disagree	1 2 3 4 5	Strongly Agree

29. When I see a chemical formula, I try to picture how the atoms are arranged and connected.

Strongly Disagree	1 2 3 4 5	Strongly Agree

30. In chemistry, mathematical formulas express meaningful relationships among measurable quantities.

Strongly Disagree	1 2 3 4 5	Strongly Agree

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree (not strongly agree) for this question.

Strongly Disagree	1 2 3 4 5	Strongly Agree

32. It is important for the government to approve new scientific ideas before they can be widely accepted.

Strongly Disagree	1 2 3 4 5	Strongly Agree

33. The arrangement of the atoms in a molecule determines its behavior in chemical reactions.

Strongly Disagree	1 2 3 4 5	Strongly Agree

34. Learning chemistry changes my ideas about how the world works.

Strongly Disagree	1 2 3 4 5	Strongly Agree

35. To learn chemistry, I only need to memorize how to solve sample problems.

Strongly Disagree	1 2 3 4 5	Strongly Agree

36. Reasoning skills used to understand chemistry can be helpful to me in my everyday life.

Strongly Disagree	1 2 3 4 5	Strongly Agree

37. In learning chemistry, I usually memorize reactions rather than make sense of the underlying physical concepts.

Strongly Disagree	1 2 3 4 5	Strongly Agree

38. Spending a lot of time understanding where mathematical formulas come from is a waste of time.

Strongly Disagree	1 2 3 4 5	Strongly Agree

39. I find carefully analyzing only a few problems in detail is a good way for me to learn chemistry.

Strongly Disagree	1 2 3 4 5	Strongly Agree

40. I can usually figure out a way to solve chemistry problems.

Strongly Disagree	1 2 3 4 5	Strongly Agree

41. The subject of chemistry has little relation to what I experience in the real world.

Strongly Disagree	1 2 3 4 5	Strongly Agree

42. There are times I solve a chemistry problem more than one way to help my understanding.

Strongly Disagree	1 2 3 4 5	Strongly Agree

43. To understand chemistry, I sometimes think about my personal experiences and relate them to the topic being analyzed.

Strongly Disagree	1 2 3 4 5	Strongly Agree

44. Thinking about a molecule's three-dimensional structure is important for learning chemistry.

Strongly Disagree	1 2 3 4 5	Strongly Agree

45. It is possible to explain chemistry ideas without mathematical formulas.

Strongly Disagree	1 2 3 4 5	Strongly Agree

46. When I solve a chemistry problem, I explicitly think about which chemistry ideas apply to the problem.

Strongly Disagree	1 2 3 4 5	Strongly Agree

47. If I get stuck on a chemistry problem, there is no chance I'll figure it out on my own.

Strongly Disagree	1 2 3 4 5	Strongly Agree

48. Spending a lot of time understanding why chemicals behave and react the way they do is a waste of time.

Strongly Disagree	1 2 3 4 5	Strongly Agree

49. When studying chemistry, I relate the important information to what I already know rather than just memorizing it the way it is presented.

Strongly Disagree	1 2 3 4 5	Strongly Agree

50. When I'm solving chemistry problems, I often don't really understand what I am doing.

Strongly Disagree	1 2 3 4 5	Strongly Agree

APPENDIX 16

CRE Survey

In identifying yourself, please provide the name of your University Hall and your favorite course code.

Name of University hall: …………………. Favorite course code: …………….

The following are number of statements that may or may not describe your beliefs in the use of indigenous knowledge in learning various concepts of chemistry. Circle the number that best describes what you think about these statements where the numbers mean the following:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree

There are no 'right' or 'wrong' answers. Your opinion is what matters. Be sure to provide answers for all questions. If there is change of mind to an answer already selected, kindly cross it out and circle another.

Table S6. Survey conducted for the study.

Survey	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I study chemistry to gain knowledge that will be useful in my life outside the school	1	2	3	4	5
Studying chemistry changes my ideas about how the world works.	1	2	3	4	5
I find chemistry applicable to everyday life and also to that of my ancestors.	1	2	3	4	5
Knowledge in chemistry is made up of several related topics that build on each other.	1	2	3	4	5
Understanding the concepts in chemistry basically means being able to recall or connect with what you practice or experience every day in life.	1	2	3	4	5
To understand chemistry, I think using cultural knowledge and practices that include its applications is a good way to study it.	1	2	3	4	5
Connecting ideas that use cultural history with chemistry can help me understand chemistry better.	1	2	3	4	5
When studying chemistry, I relate important information to what I already know rather than just memorizing from textbooks or notes.	1	2	3	4	5
To understand a chemical reaction and processes, I think about the reactions and processes that are in my environment.	1	2	3	4	5

Table S6. Survey conducted for the study continued.

Survey	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Indigenous or cultural practices related to chemistry can make the unfamiliar chemistry content familiar to students.	1	2	3	4	5
The relationship between indigenous or traditional practices and modern scientific approaches represents a continuum of scientific knowledge.	1	2	3	4	5
Indigenous and cultural knowledge adds a meaning to chemistry that is not possible by just studying modern practices.	1	2	3	4	5
Indigenous or cultural knowledge has increased my intellectual curiosity and the desire to study chemistry.	1	2	3	4	5

Table S6. Survey conducted for the study continued.

Survey	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can see that knowledge and use of chemistry in daily life is also a part of my cultural heritage.	1	2	3	4	5
I think indigenous or cultural knowledge can be used to understand processes in detail and to draw connections of these processes with current scientific practices.	1	2	3	4	5
I would like to see more modules and resources in chemistry that use examples to connect traditional cultural practices with modern sciences, especially chemistry.	1	2	3	4	5