THE EFFECT OF THE CONCEPTUAL CHANGE PROCESS ON STUDENT ALTERNATIVE CONCEPTIONS AND CONFIDENCE IN SCIENCE

by

Carolyn Ranae Pincock

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TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND vi

Context of Study 1
School Demographics 2
Focus Questions 3

2. CONCEPTUAL FRAMEWORK 4

Introduction 4
Alternative Conceptions 5
Conceptual Change Process 7
Instructional Strategies 9
Conclusion 10

3. METHODOLOGY 12

Demographics 12
Treatment 13
Data Collection and Analysis Strategies 15
Pre- and Post-Assessment Probes 18
Exit Tickets 20
Interviews 21
Evidence-based Argumentative Writing 22
Color Coded Concept Map 23
Conclusion 24

4. DATA ANALYSIS 25

Pre-Assessment Probe Insights 25
Terminology Accuracy 27
Water Cycle Sketches 29
Student Confidence in Knowledge 32
Impacts on Student Comprehension 34
Impacts on Student Confidence 38

5. CLAIM EVIDENCE AND REASONING 40

Claims From the Study 40
Impact of Conceptual Change on Student Comprehension and Confidence 41
Impact of Conceptual Change Process on Student Comprehension 41
Impact of Conceptual Change Process on Student Confidence 42

TABLE OF CONTENTS CONTINUED

Value of the Study and Consideration for Future Research 43
Impact of Action Research on the Author 44

REFERENCES CITED 47

APPENDICES 50

APPENDIX A: IRB Approval 51
APPENDIX B: Pre- And Post-Assessment Probe 53
APPENDIX C: Exit Tickets 55
APPENDIX D: Interview Sample Questions 57
APPENDIX E: Coded Concept Map 59
APPENDIX F: Data Analysis Tables and Graphs 61

LIST OF TABLES

Table Page

1. Data Triangulation Matrix. 16
2. Assessment Probe Rubric 19
3. Self-scoring Student Confidence Scale..... 20
4. Pre-assement Probe Terminology Accuracy by Terms 28

LIST OF FIGURES

Figure Page

1. Plan for Creating the Conceptual Change Process 14
2. Water Cycle Content Knowledge and Confidence Weakness 26
3. Pre-Assessment Vocabulary Probe Accuracy 27
4. Pre-Assessment Probe Rubric Scores for Water Cycle Sketches 30
5. Pre-Assessment Probe Student Water Cycle Sketch 31
6. Pre-Assessment Probe Self-rated Student Confidence Percentages 33
7. Pre- and Post-Assessment Terminology Result Comparison 35
8. Comparison of Pre- and Post-Assessment Rubric Scores 36
9. Comparison of Average Sketch Rubric Scores between Assessment Probes 37
10. Pre- and Post-Assessment Probe Self-Rated Confidence Percentages 38
11. Student Confidence Level Comparison between Assessment Probes 39
12. Image of Infiltration Exploration Station 44

ABSTRACT

Educators encounter students in the classroom with diverse understandings of the natural world, conceptions that have been influenced by life experiences in and out of academic settings. These differing conceptions can often be incomplete or mistaken, termed as alternative conceptions, which can hinder current and future learning, potentially undermining students' confidence. To counter this issue, it is mandatory to identify and address students' alternative conceptions. For this study, a strategically planned learning process was implemented. A part of this process, a pre-assessment probe was implemented at the beginning of the water cycle unit. Students' probe responses identified pointed weakness in terminology comprehension, multiple alternative conceptions, and low confidence in students' knowledge about the water cycle. Based on these findings, a range of instructional methods was selected to confront and rectify any alternative conceptions—a process termed the conceptual change process. Instructional strategies included exploration stations, hands-on labs and activities, concept maps, evidence-based argumentative writing, exit tickets, class discussions, interviews, and student reflections. During each brief instructional opportunity, students focused on confronting their content conceptions. Over the span of four weeks, the multi-purpose instructional strategies provided quantitative and qualitative data and collectively contributed to a comprehensive understanding of the impact on students academically, mentally, and emotionally. Students' comprehension increased in their terminology comprehension accuracy and their ability to create a comprehensive sketch of the water cycle. They showed a significant surge in confidence in their understanding of the water cycle with 78% of students rating themselves confident or highly confident in their knowledge.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of Study

In science education, addressing misconceptions and facilitating the conceptual change process is a vital academic undertaking. Students often enter the learning environment with pre-existing ideas about scientific phenomena, some of which may be inaccurate or incomplete. For instance, the once common belief of spontaneous generation fostered interesting recipes for living organisms such as bees and mice. Seventeenth century Flemish scientist Jan Baptiste van Helmont created a recipe and procedure for creating mice – throw some dirty clothes or rags in an open barrel or container containing a few grains of wheat or wheat bran. After 21 days, there would be male and female mice capable of reproducing more mice (Gaud, n.d.). More recently is a common misconception that seasons are solely determined by the varying distances between the Earth and the Sun throughout the year as shown by research completed by Slater et al. (2015) on responses to the Test of Astronomy Standards (TOAST) test. To initiate the conceptual change process, educators must first identify and acknowledge these misconceptions. Subsequently, targeted instructional strategies, such as hands-on labs, evidence-based argumentative writing, concept mapping, and a variety of formative assessments can be utilized to challenge and revise students' misconceptions. By fostering an environment that encourages active engagement and reflection, educators can guide learners toward a deeper and more accurate understanding of scientific concepts, thereby promoting conceptual change and facilitating meaningful learning experiences.

School Demographics

In July 2022, I accepted a middle school science teaching position at Oak Grove Elementary. Located in Bartonville, Illinois, Oak Grove serves 279 students from preschool through eighth grade and is one of eight feeder schools to the community high school. According to the Illinois 2023 Report Card, 41% of the school's student population are classified as low-income. Ethnic diversity is divided along the following lines: 87.8% of students are White, 4.3% are Black, and 6.1% are two or more races. Almost 21% of students are chronically absent with a truancy rate of 12.2% and mobility rate of 7.5%. Eighteen percent of the student population have an individualized education plan (IEP). These IEP plans accommodate for wide range of disabilities: autism (18%), developmental delays (16%), emotional (5%), hearing impairment (2%), intellectual ability (3%), orthopedic impairment (3%), other health impairments (22%), specific learning disability (11%), and speech or language impairment (21%).

Beginning with kindergarten, each grade level has two classrooms. Kindergarten through fourth-grade classes are self-contained. Once in fifth grade, students begin rotating classes for core academic classes as well as physical education, health, technology, art, music, and enrichment or intervention based on student need. The science classes I teach include one of the fifth-grade classes and all the sixth through eighth grade classes. There are 92 students on my roster: 13 fifth graders, 30 sixth graders, 24 seventh graders, and 25 eighth graders which are divided into two classes for each grade level except fifth grade. Comparable to the general school demographics, of these 92 students, 6.5% of these students identify as Black or multiple races. Sixteen percent of these students are chronically absent with a 1% truancy rate. The percentage of students with an IEP is 17.8% and includes students with autism, hearing impairments, emotional disabilities, health impairments, and learning disabilities. Identifying student misconceptions, implementing effective instructional strategies, and consistently assessing

students' understanding amidst diverse life experiences and academic purposes presents a challenge, especially while also addressing students' mental and emotional needs. The purpose of this research was to observe how the implementation of the conceptual change process affected the identified misconceptions students held and what impact this process had on student mentality such as confidence.

Focus Questions

My focus question was, How does implementing the conceptual change process affect student comprehension and confidence?

My sub-focus questions include the following:

1. How does student involvement in the conceptual change process affect content understanding?
2. How does student confidence change during the conceptual change process?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

For millennia, individuals and societies have tried to understand the world around them. The perceived movement of the sun and natural disasters were often attributed to the power of mythological deities. Alfred Wegener, a German scientist who proposed the theory of continental drift, believed centrifugal and tidal forces caused the continents to move through Earth's crust (NASA, 2001). Inaccurate perceptions existed because of individual life experiences, current knowledge, miscommunications, or even cultural barriers. Wegener's theory of continental drift became the foundation of our knowledge of plate tectonics through the aid of improved technology. As individuals and societies continue to try to understand and make sense of the world around them, there will be alternative conceptions.

Today students enter the classroom with previously constructed conceptions about the world around them. These perceptions of the natural world are personal because they are influenced by their life experiences, communications with others, social media, lack of digital literacy skills, and even previous classroom lessons or the lack thereof. However, since building upon unstable scientific knowledge can interfere with and impede further learning, an inaccurate understanding can create an unstable learning foundation riddled with errors (Gooding & Metz, 2011). One example that comes to mind is a sixth-grade student who expressed the idea that underwater volcanoes do not exist. What experiences would lead to this alternative conception? It is important to elicit and understand the type of alternative conceptions students possess. The first step in the conceptual change process is to expose students' preconceived notions and

address their areas of weakness so a stronger foundation of scientific knowledge can be built (Lucariello, 2015). Additionally, a range of instructional strategies will be examined to identify how they may aid in the conceptual change process and observe how this process manifests in the classroom.

Alternative Conceptions

Alternative conceptions, also referred to as misconceptions, are semi-accurate or inaccurate assumptions of the world around us. Taber (2023) explains that "an alternative conception is a conception or way of thinking about something alternative to and inconsistent with the versions of concepts particular academic communities currently hold, or canonical concepts" (para. 5). Children's book author Leo Lionni (1995) illustrated how an individual's understanding (or fish in this instance) is based upon their personal experience: "As the frog talked, his friend saw the birds fly through his mind like large feathered [sic] fish" (p. 14). When an individual's experiences are limited, their ability to make sense of what they observe is also limited. This limitation can lead to acquired alternative conceptions.

Alternative conceptions can develop for various reasons. An example of an alternative conception revolves around the Earth and the sun. While growing up, children hear that the sun rises and sets, giving the impression that the sun is moving not the Earth. By the time they enter school, alternative conceptions can already be firmly established. Everyday encounters with the natural world, language barriers, books, media, and even classroom experiences can influence students as they develop their understanding of science content (Keeley, 2012; Wenning, 2008). The National Research Council (1997) identified five types of alternative conceptions: (a) preconceived notions, (b) nonscientific beliefs, (c) conceptual misunderstandings, (d) vernacular misconceptions, and (e) factual misconceptions. Each type of alternative conception alludes to

how it was formed. Preconceived notions are rooted in everyday experiences while nonscientific beliefs stem from religious or mythical teachings. The National Research Council (NRC) continued to explain that conceptual misunderstandings "arise when students are taught scientific information in a way that does not provoke them to confront their preconceived notions and nonscientific beliefs" (p. 28). Vernacular misconceptions occur due to the use of words that have one meaning in everyday life and another in a scientific context. An example would be the term work or acceleration when discussing the concepts of motion and energy. The NRC (1997) warned that "when falsities learned in childhood are not challenged and are retained into adulthood, factual misconceptions can occur" (p. 28). An example of this is the old wives' tale that cold weather causes the common cold. Insight into why a student forms alternative conceptions can raise awareness and influence an educator's teaching method and how to address these incorrect or incomplete conceptions. Becoming cognizant of what, how, and why an alternative conception occurred can lead to improved understanding for the student and awareness on behalf of the teacher.

Even after being revealed, some alternative conceptions can be deeply embedded in student thinking. The likelihood of a misconception becoming entrenched increases the longer it remains unchallenged, increasing the possibility of the interpretation of new experiences through a convoluted lens of understanding. However, identifying and recognizing an alternative conception is just one aspect of the solution (Gooding & Metz, 2011; Lucariello, 2015). Taber (2023) explained that "people's conceptions vary across a range of dimensions which affects teaching and learning" (para. 11). There are five dimensions of conceptions that range in lability and inertness, meaning how likely the conceptions are to change, and how much they lack vigor or strength. The dimensions are defined by Taber as follows:

1. *Canonicity* is the extent to which a person's conceptions match or are inconsistent with the concept currently held by the science community.
2. *Acceptance* is how strongly committed the person is to the idea. Do they strongly believe it or just think it might be the case?
3. *Connectedness* is the extent to which the conception is linked with other conceptions. Is it part of an extensive conceptual framework?
4. *Multiplicity* describes their way of making sense. Is it their only way of making sense or among several possibilities?
5. *Explicitness* is how open to conscious reflection the conception is.

The methods used to address students' alternative conception depend on the type and dimension of the alternative conception. The collection of these methods – the conceptual change process – serves the purpose of addressing misunderstandings as well as preventing further experiences and learning from being tainted.

Conceptual Change Process

The conceptual change process assists students in building a more secure knowledge base through non-traditional instructional strategies. Duit (2003) describes conceptual change as the construction of learning pathways from where the student is currently in their understanding to the science concepts to be learned. The National Research Council (1997) clarified that before students can "embrace the concepts held to be correct by the scientific community," they must "confront their own beliefs along with their associated paradoxes and limitations before attempting to reconstruct the knowledge necessary to understand the scientific concept being presented" (p. 29). Keeley (2012) agrees that it "is important to provide instructional experiences that will confront student thinking and guide them" rather than force a change in thinking (p. 13).

Allowing students to become an active part of the learning process allows the learning experiences to become part of a solid foundational knowledge base, and for meaningful learning to occur, new knowledge must relate to previous preconceptions (Kyle et al., n.d.). Teachers must first identify students' misconceptions. Second, they need to provide a forum for students to confront their alternative conceptions, and lastly, teachers should help students reconstruct and internalize their knowledge, based on scientific models (National Research Council, 1997). The conceptual change process is a conscious effort that relies on teacher observation and insight that allow students to construct and build upon their learning experiences. This partnership can create opportunities for students to use the implemented instructional strategies to connect their conceptions and broaden their understanding.

One or two quick classroom activities will not change a student's alternative conception that has developed over an extended period. Heal (2023) stated that

> Any new knowledge a learner may encounter needs to be able to attach itself to their existing knowledge – otherwise it won't stick. New knowledge must be built on and attached to prior knowledge. In other words, new and old knowledge behaves like two halves of a Velcro strip. … Knowing this is significant because it opens a space for instruction to be both teacher-led and student-centered.

Educators need to create a teacher-guided, scaffolded learning environment that gives students opportunities to successfully grasp the concept and securely place it in their conceptual framework. For new conceptual learning to develop, Wenning (2008) explains it must meet the following three requirements:

1. It must be intelligible. Can students comprehend its meaning?
2. It must be plausible. Do students believe it to be correct?
3. It must be fruitful. Do students find it useful?

The instructional strategies employed to address alternative conceptions need to provide consistency, create connections, and prove beneficial to the student. No one or even two strategies can provide these velcro experiences for students who may have deep-rooted alternative conceptions.

Instructional Strategies

A classroom of students can reveal a wide range of cognitive abilities, learning styles, and knowledge levels, which creates a demand for a variety of instructional strategies. Several instructional strategies help educators implement the conceptual change process and include assessment probes, models, exploration labs, and evidence-based arguments (Lucariello, 2015). Since alternative conceptions can occur for a variety of reasons, an array of teaching strategies and tools can aid in addressing them. Gooding and Metz (2011) stated that despite our best efforts, students will continue to create their reality based on their individual experiences and, for this reason, no instructional strategy is a one-size-fits-all approach. Students require a variety of strategies to meet their needs. Students would benefit from their learning if educators supplied strategies to meet their knowledge and comprehension needs.

How can educators know what strategies and instructional methods students would benefit from? Sutton (2021) states that teachers will "promote enduring student comprehension" if they can identify and use what the student thinks they might know about a concept (p. 70). Keeley (2016) explains that teachers should use Formative Assessment Classroom Techniques (FACTs) to assist in student learning while at the same time, the teacher is gathering valuable information about student thinking that will inform instruction and provide feedback. FACTS can serve an instructional, assessment, and/or learning purpose. Keeley further states that

> these techniques engage students in thinking about their ideas in science, uncover preexisting ideas students have that can be used as starting points to connect with new concepts, and help both students and teachers through the learning cycle to understand their progress (pp. 3-4).

When teachers are aware of a student's alternative conception, they can help that student reconstruct their thinking and understanding which can create a more stable knowledge foundation upon which to build. Lucariello (2015) explained that "generally, ordinary forms of instruction, such as labs, discovery learning, or simply reading texts, are not very successful at overcoming student misconceptions" (para. 3). Keeley stated that some beneficial techniques include having students share pre-existing conceptions through writing, using students' prior knowledge of the current concept, using model-based reasoning, increasing student metacognition, presenting experiences that cause cognitive conflict. Lucariello explained that such learning opportunities allow students to "self-repair their misconceptions" (para. 1). The array of instructional strategies allows students to play a vital role in becoming aware, challenging their thinking, and building upon their knowledge. Educators should employ strategies that are teacher-guided and student-centered because through these types of strategies effective and meaningful conceptual change can occur.

Conclusion

By employing formative assessments and observation, educators can elicit student conceptions about science topics. Keeley (2012) counsels that it is important to "identify the type of alternative conception a student has before using it as a springboard to guide them through conceptual change" (p. 15). Providing non-traditional learning opportunities for students to experience phenomena to create cognitive conflict helps them confront and resolve their conflicting perspectives between their prior and current experiences (Wenning, 2008). Students

should be allowed to actively connect prior understanding to new experiences, velcroing them together to fortify and strengthen their foundation of scientific knowledge. These experiences will help students better and more confidently understand the natural world around them.

CHAPTER THREE

METHODOLOGY

Demographics

In the middle school science classroom, diverse alternative conceptions about the hydrological cycle and its elements were observed among students. Taber (2023) explained that an alternative conception is a conception or way of thinking about something that is inconsistent or altered from the version held canonical concepts. Not all the ideas are correct or complete, and the incorrect or partially formed conceptions students have about the natural world can interfere with their understanding of topics that build upon each other, making the foundation of their understanding weak. These alternative conceptions adversely impact the foundational understanding of scientific content for students, potentially posing impediments to their subsequent learning experiences and eroding their confidence.

A significant challenge involved effectively recognizing students' alternative conceptions and addressing them in a manner aligned with their academic and cognitive requirements. To gain insights, this research centered on the following questions:

1. How does implementing the conceptual change process affect student comprehension and confidence?
2. How does student involvement in the conceptual change process affect content understanding?
3. How does student confidence change during the conceptual change process?

The purpose of this research was not only to explore how the conceptual change process affected students' ability to make accurate claims and provide evidence and reasoning to support

those claims but the effect this process had on students' confidence in their ability to provide evidential support for their claims. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

With the water cycle as the unit of study used for this research, the two sixth-grade Earth science classes were selected as the test group. It is important to understand the complex relationship between students' diverse backgrounds and life experiences, their comprehension of the natural world, and the aspects of the conceptual change process. Within the two classes, 6A and 6B, students have varied cultural, socio-economic, and academic profiles. These individual differences influence the prevalence of alternative conceptions and helped influence the selection of instructional tools and methods during the exploration of the hydrological cycle. Of the 30 participating students, 53% identified as female (n=16) and 47% identified as male (n=13). Most students were non-Hispanic White (n= 27) while 10% of the students are Black or individuals of multiple races (n=3). Additionally, 17% of the students (n=5) had an individualized education plan (IEP). The differences in all the students' abilities and backgrounds played a factor not only in students' alternative conceptions held but also the selection of instructional tools and methods implemented during the conceptual change process.

Treatment

Multiple alternative conceptions had been observed in the classroom, but there was not a systematic approach in addressing these issues or an understanding of how these ideas might affect student confidence levels. As shown in Figure 1, a process was created to address these issues or concerns, beginning with identifying student beliefs and knowledge.

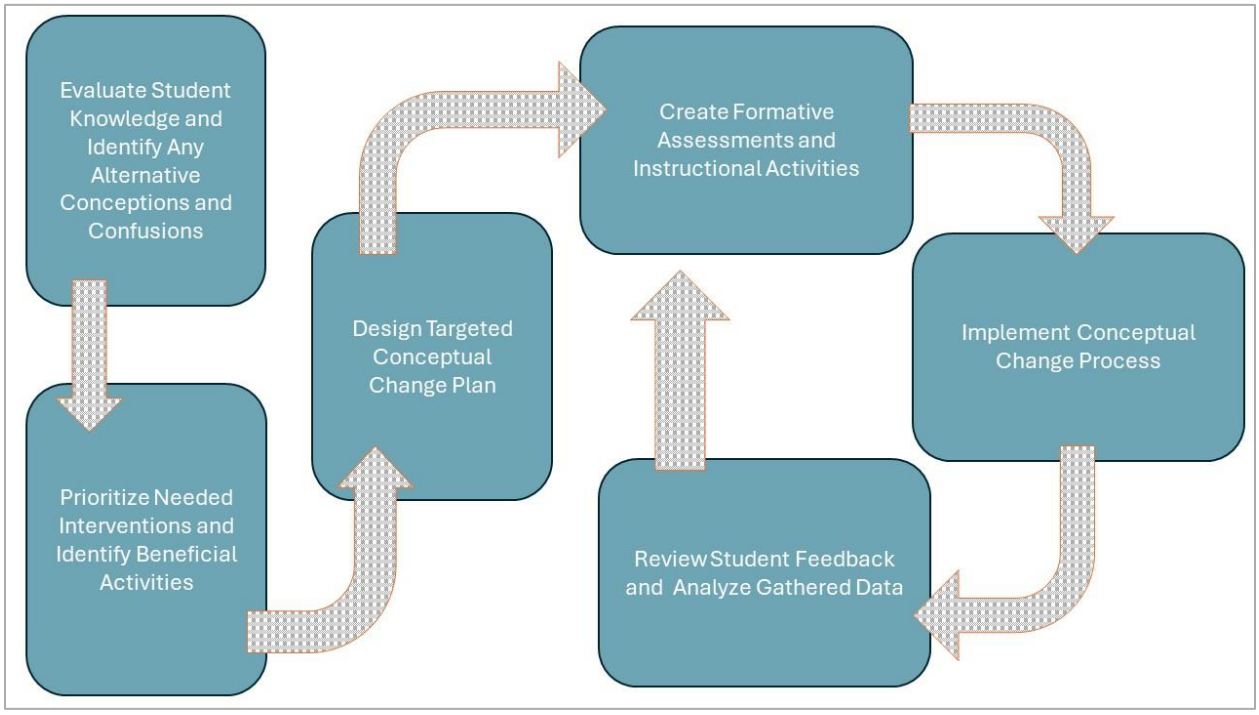


Figure 1. Plan for Creating the Conceptual Change Process.

According to Ausubel et al. (1978, as cited in Keeley, 2016), "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly" (p. ix). The first step was to evaluate what the learner, the student knows. To assess the students' prior knowledge, the Pre-Assessment Probe was administered before beginning the unit on the hydrological cycle (Appendix B). After evaluating the students' responses and the identification of any alternative conceptions, instructional strategies and activities were developed and applied to target the alternative conceptions students held and hindered their comprehension.

The activities and instructional methods used included models, exploration labs, evidence-based argumentative writing, exit tickets, class discussions, interviews, and a post-assessment probe. Konicek-Moran and Keeley (2015) explained that students understand a concept when

> they can (a) think with it, (b) use it in other areas than that in which they learned it, (c) state it in their own words, (d) find a metaphor or analogy for it, or (e) build a mental or physical model of it (p. 6).

Each method and learning opportunity was selected to allow students to become aware of their own thinking or metacognition. In explaining their list of dos and don'ts, Lucariello and Naff (2015) stated that helping students become aware of their own alternative conceptions can lead to change in these conceptions and the learning of new concepts and theories. The choice of using probes, models, discussions, evidence-based argumentative writing, phenomenon, exploration labs, interviews, and reflection provided an array of opportunities for students to confront their understanding, challenge it, build new understanding, and connect it to the experiences in their own lives. As students gain insight into their own understanding, they can feel more confidence in their ability to explain and strengthen their newly acquired correct knowledge.

Data Collection and Analysis Strategies

Continuous change is one of the few unchanging realities. Fowler et al. (2019) stated that the ideas students bring to class and their perspectives on what is happening in the classroom change constantly. How educators keep track of students' ever evolving ideas and understanding is important. To track these changes, educators can rely on and implement a plethora of tools and instruments. Keeley (2019) explained the purpose of these techniques and instruments:

> These techniques are used to engage students in thinking deeply about their ideas in science, uncover the preexisting ideas students bring to their learning that can be used as starting points to build on during instruction, and help teachers and students throughout an instructional cycle determine how well individuals and the class are progressing toward developing scientific understanding (p. 4).

Various data collection methods were employed to study the impact of the conceptual change process on students' content understanding as well as their confidence in that knowledge. Each data collection tool was crafted to gather both quantitative and qualitative data (Table 1). Mertler

(2020) explains that the usage of both types of data provides a more comprehensive overview and understanding of the research problem or focus.

Table 1. Data Triangulation Matrix.

	Focus Questions		
Data Collection Instruments	How does implementing the conceptual change process affect student comprehension and confidence?	How does student involvement in the conceptual change process affect content understanding?	How is student confidence changed during the conceptual change process?
Pre-Assessment Probe	X	X	
Exit Tickets	X	X	X
Interviews	X	X	X
Evidence-Based Argumentative Writing	X	X	
Coded Concept Map	X	X	X
Post-Assessment Probe	X	X	

The collection of quantitative data provided insight into what the students knew and how confident they felt regarding their understanding. The understanding of why and how students formed these alternative conceptions was provided through the collection of qualitative data. Together the data provided a comprehensive understanding of the impact the conceptual change process had on student alternative conceptions and confidence levels.

Through the collection of non-anonymous mixed-methods data, it became possible to both individually and collectively monitor shifts in students' content understanding and

confidence. Keeley (2016) explains that formative assessment techniques such as those used in this study

> inform teaching by allowing the teacher to continuously gather information on student thinking and learning to make data-informed decisions to plan for or adjust instructional activities, monitor the pace of instruction, identify potential misconceptions that can be barriers as well as springboards for learning, and spend more time on ideas that students struggle with.…provide feedback to students, engaging them in the evaluation of their own and their peers' thinking and learning (p. 5).

This gathered information signaled any need for semi-structured interviews, additional exploration labs or modeling, small group instruction, or other adaptations to instructional activities as part of the conceptual change process.

In addressing the core question of this research—whether engaging in the conceptual change process rectifies students' alternative conceptions and its impact on confidence—diverse data analysis techniques were employed to assess the collected data. The study delves into evaluating relationships between the conceptual change process and student comprehension, as well as between student comprehension and confidence. According to Jung and Randall (2018), correlation analysis among these variables is deemed crucial. A comparison of self-assigned student confidence scores at the beginning and end of the unit facilitates tracking changes in confidence levels throughout the conceptual change process. This comprehensive approach enhances the understanding of how alternative conceptions are rectified and the subsequent impact on student confidence.

Pre- and Post-Assessment Probes

The alternative conceptions held by students pose barriers and impede their capacity for learning. Gooding and Metz (2011) cautioned that an inaccurate understanding can create an unstable learning foundation riddled with errors since building upon unstable scientific knowledge can interfere with and impede further learning. To identify the alternative conceptions and reasoning behind the students' thought processes, the Pre-Assessment Probe was used prior to the unit (Appendix B). The probe provided data about where students are and how to address alternative conceptions. Without the information supplied by the Pre-Assessment Probe, it was impossible to formulate a treatment plan. Integral to the research, this strategic plan centered around enabling students to face their misconceptions and undergo a process of self-repair within the conceptual change framework.

Having explored the significance of identifying alternative conceptions and the pivotal role of the Pre-Assessment Probe in shaping instructional strategies, the subsequent focus shifts to the execution and evaluation of the conceptual change process in addressing these misconceptions. Keeley (2016) explained that a teacher can collect data to identify the commonly held ideas students have about a phenomenon. However, it is merely a diagnosis if the data are not used to inform teaching and learning. The Pre-Assessment Probe helped not only diagnose the problem but provided directions to the instructional strategies and methods needed to correct student alternative conceptions. The same probe was given as a post-assessment and provided follow-up data at the end of the conceptual change process (Appendix B). Due to the dual role of the assessment probe, alternative conceptions were identified, an instructional plan was developed, and data was collected to ascertain the effectiveness of the conceptual change process.

With an understanding of the instructional foundation laid by the Pre-Assessment Probe, the focus shifted to the practical evaluation of students' comprehension of the water cycle. This involved a dual-scoring approach, combining a simple count and a rubric-based assessment, aiming to provide a thorough examination of the effectiveness of the conceptual change process in addressing and rectifying misconceptions about the water cycle. The first part of the scoring system involved a simple count of the 20 listed elements, while the second employed a five-level rubric (Table 2) assessing sketches and explanations provided by students on the probe. This rubric design mirrored the one utilized by Cardack (2009) in a study examining student misconceptions about the water cycle.

Table 2. Assessment Probe Rubric.

Level 1	Level 2	Level 3	Level 4	Level 5
No sketch was provided or an answer of "I don't know" was given if any answer was provided	Sketches lack representational qualities but have some identifiable water cycle elements OR responds with diagrams rather than sketches	Sketches indicate some degree of understanding but include some level of misconceptions regarding the water cycle	Incomplete sketches depicting certain elements of the water cycle (clouds, rain, evaporation, etc.), suggesting a limited understanding	Comprehensive representation sketches that reveal a sound awareness of the water cycle and contained seven or more elements of the water cycle

Each level of the rubric assessed students based on their conceptual understanding. Upon using the Post-Assessment Probe and the rubric (Table 2), students' responses were analyzed and compared to the Pre-Assessment Probe scores to identify any changes. The dual scoring systems offered a comprehensive evaluation of students' evolving comprehension of water cycle elements. This systematic approach, combining both counting and rubric-based assessments, allowed for a thorough examination of the effectiveness of the conceptual change process in rectifying misconceptions about the water cycle.

Exit Tickets

As students underwent the learning process, their evolving conceptions and comprehension were effectively monitored through the strategic use of exit tickets, as suggested by Fowler et al. (2019), providing valuable insights into changes in understanding, identification of alternative conceptions, and the impact on student confidence level. Fowler et al. (2019) defined exit tickets as short response tasks given to students after an activity or class period. The Exit Tickets were administered to students following exploration labs and creation of models and collected data about student comprehension and confidence in their understanding about the concept taught and discussed during the lesson (Appendix C). Given as a Google Form, each exit ticket consisted of one to two concept-focused questions, a place to upload a digital file, and self-scoring confidence scale to rate students' confidence with their understanding (Table 3).

Table 3. Self-scoring Student Confidence Scale.

How confident are you with your answer?				
No confidence 0	Little Confidence 1	Some Confidence 2	Confidence 3	High Confidence 4
Explain the reason for your choice.				

Review of the exit ticket data helped explore (a) the relationships among the assessment probe's words, (b) any newly acquired or persistent alternative conceptions, and (c) students' confidence levels. This examination provides valuable insights into effective instructional strategies, areas of both proficiency and deficiency in student comprehension, and any influence on student confidence. Additionally, the Exit Tickets provided the opportunity for students to share their

understanding about specific water cycle content and elements. While enlightening, this data represents only a portion needed. A complementary perspective was necessary to gain a better vantage point to view student understanding and confidence levels.

Interviews

Building on the insights gained from other tools' data, interviews gave both a complementary and more general perspective of student understanding, a contrast to the concept-specific exit tickets. Professor Julie Slayton (2018) explained that the purpose of the interview is to gain insight into somebody's perspective to gain understanding in connection to the research question being asked. During the conceptual change process, students were given a series of questions related to the content taught and explored during a given time (Appendix D) and recorded their answers in a video format. This collection method allowed students to record in a more comfortable, secure setting. One disadvantage of the structured method was the brief responses that did not provide enough information or insight into student understanding. However, the use of a video platform for recording student responses created time to conduct semi-structured interviews as needed for follow-up. Using both structured and following up with semi-structured interviews allowed the ability to collect the needed data from students along with the flexibility to gain further insight into the use of content specific words, any retained alternative conceptions, muddy points or confusions, and feedback about treatment activities.

Close-ended questions like "Are you confident in explaining evaporation?" yielded concise answers, providing quantitative research data and ensuring consistent individual and collective data throughout the conceptual change process. However, this method does not provide qualitative data that would create a more comprehensive picture when coupled with the quantitative data. Professor Slayton (2018) explained that it is rich, descriptive data that is

needed to answer research questions. Qualitative data is needed to not only assess a student's ability to explain the scientific concept but why their confidence has changed, and such answers need a vivid narrative. When partnered with the same 5-point rubric used for the exit tickets (Table 3), students explained why they felt that level of confidence. When combined with the ability to ask follow-up questions, a more vivid picture of the students' journey through the conceptual change process was created. When used with other data collection such as evidence-based argumentative writing, this multifaceted approach not only deepened understanding but also allowed for a comprehensive exploration of the transformative learning experiences students underwent.

Evidence-Based Argumentative Writing

Students' advancement through the conceptual change process was expanded upon through the utilization of evidence-based argumentative writing. Khishfe (2009) reported that student engagement in argument construction improves their understanding. Using Evidence-Based Argumentative Writing requires students to evaluate not only their claim but provide evidence to support that claim. Students completed Evidence-Based Argumentative Writings using the claim-evidence-reasoning (CER) format. The CER writing activity was used throughout the water cycle unit at varying points in the treatment process as bell work, mid-class formative assessment, or an exit ticket when water cycle concepts were introduced and reviewed. In addition to using constructed argumentative writing as a treatment, it served as a qualitative data collection instrument. When used before specific content instruction and activities as a bell ringer, CER writing was used as an informal concept pre-assessment. The integration of mid-lesson writing activities along with Coded Concept Maps facilitated the observation of how student comprehension was influenced and offered valuable feedback in shaping the conceptual

change process. When complemented with CER writing as exit tickets, this combination gauged current understanding and served as a roadmap, allowing exploration of student growth when compared with pre-assessment probes and earlier formative assessments.

Coded Concept Map

As with all the included data collection instruments for this research, the use of a coded concept map served a dual purpose – to allow students to view and confront their conceptual understanding and gather data to assess any impact the conceptual process had on student understanding. The website The Teacher Tool Kit (2017) defines concept maps as "visual representations students create to connect ideas, concepts, and terms" and a way to organize information they know so that an educator can see how students understand concepts (para. 1). Using AI and the prompt "how to create a color-coded concept map," a bubble concept map was modified to assess student understanding of concepts and connections while identifying the students' level of confidence about the information shared (Appendix E). Students first identified key concepts and how they are related to the topic of study. Then using a stop light color code system, students identified their level of confidence as it applied to the concepts – green for high confidence, yellow for moderate confidence, and red for low confidence (OpenAI, 2023). The visual nature of the concept map allowed observation of included and omitted content elements while the color-coding allowed assessment of students' confidence in their content understanding. A primarily green concept map indicated a higher level of student confidence whereas a higher occurrence of red and yellow indicated a lower level of student confidence. Used in conjunction with the other treatment methods and data collection tools, these Color-coded Concept Maps provided data for each focus question: (a) assessing student understanding,

(b) how the conceptual change process affected it, and (c) the impact on student confidence levels.

Conclusion

The methodology employed in this research encompasses a multifaceted approach, incorporating multiple dual-purpose instruments designed not only for treatment but also for comprehensive data collection. By integrating mixed-methods data, a greater depth in understanding of students' alternative conceptions was gained. This data also provided insight into the effect the conceptual change process had on those conceptions and student confidence levels as they confronted and repaired those beliefs. The examination of the any shift in student comprehension and confidence was facilitated by employing a variety of tools, such as assessment probes, exit tickets, interviews, evidence-based writing activities, and coded concept maps. The goal of this action research was to provide a thorough understanding of the conceptual change process and its implications for student learning, thereby contributing not only the effectiveness of the conceptual change process but to a broader view of effective educational practices.

CHAPTER FOUR

DATA ANALYSIS

The purpose of this action research study was to identify how implementing the conceptual change process would affect student comprehension and confidence. Prior to the treatment, students completed the Pre-Assessment Probe (Appendix B) to establish a starting point regarding comprehension of the water cycle and confidence in that knowledge. Quantitative data was collected from the assessment probe's vocabulary accuracy and rubric scores for the water cycle sketches as well as multiple self-scored confidence ratings. Qualitative data was collected from the water cycle sketches, student explanations and writings, and reflective interviews as well as teacher notes from informal observations during instructional activities. Using both the quantitative and qualitative data, a targeted conceptual change process was created and implemented. Following the unit, students were assessed using the Post-Assessment Probe (Appendix B) which was identical to the one given to students at the beginning of the unit. The results from both probes were compared to identify the impact, if any, of the conceptual change process on student comprehension and confidence.

Pre-Assessment Probe Insights

The Pre-Assessment Probe gathered data from three areas: (a) student understanding of associated terminology, (b) student-created sketch of the water cycle, and (c) student confidence in their knowledge of the content at that time. A quantitative data analysis revealed the results of the Pre-Assessment Probe identified weaknesses in both terminology accuracy and the ability to create a sketch of the water cycle that indicated a comprehensive understanding as shown in Figure 2.

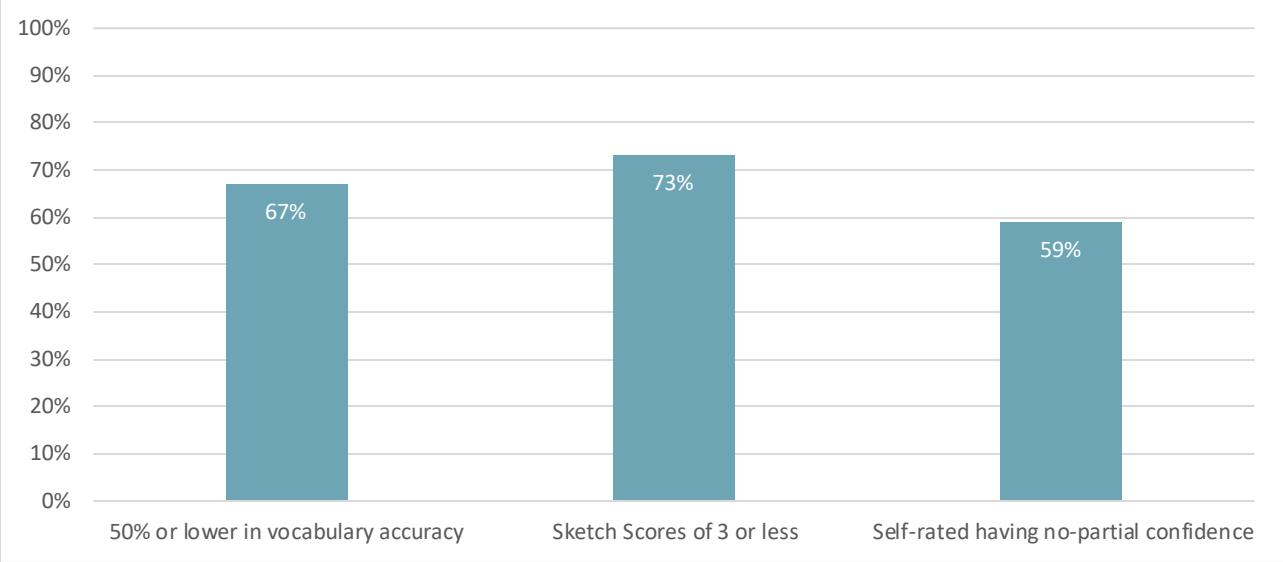


Figure 2. Water Cycle Content Knowledge and Confidence Weakness, (*n*=27). Results were drawn from students' responses to the Pre-Assessment Probe.

The continued quantitative analysis of the Pre-Assessment Probe's individual sections – terminology and water cycle sketches – highlighted specific areas of weaknesses in student's knowledge of the water cycle terminology and processes. At 67%, most of the responding students were unable to recognize at least half of the terminology associated with the water cycle. Using a rubric (Table 2), 73% of students created sketches of the water cycle that lacked complete understanding of the water cycle and exhibited alternative conceptions. These identified weaknesses and alternative conceptions were used to help create the treatment plan implemented in the conceptual change process.

Terminology Accuracy

The Pre-Assessment Probe included 20 terminology terms, each word or phrase being an element or process associated with the water cycle. Based on their knowledge at the time students were to select the terms that were part of the water cycle process. Prior to any treatment, students showed a marked weakness in a knowledge of the water cycle key terminology. As shown in Figure 3, students struggled to identify the terminology associated with the water cycle. The bulk of the students in the sample could not identify half of the terms included in the Pre-Assessment Probe as playing a role in the water cycle.

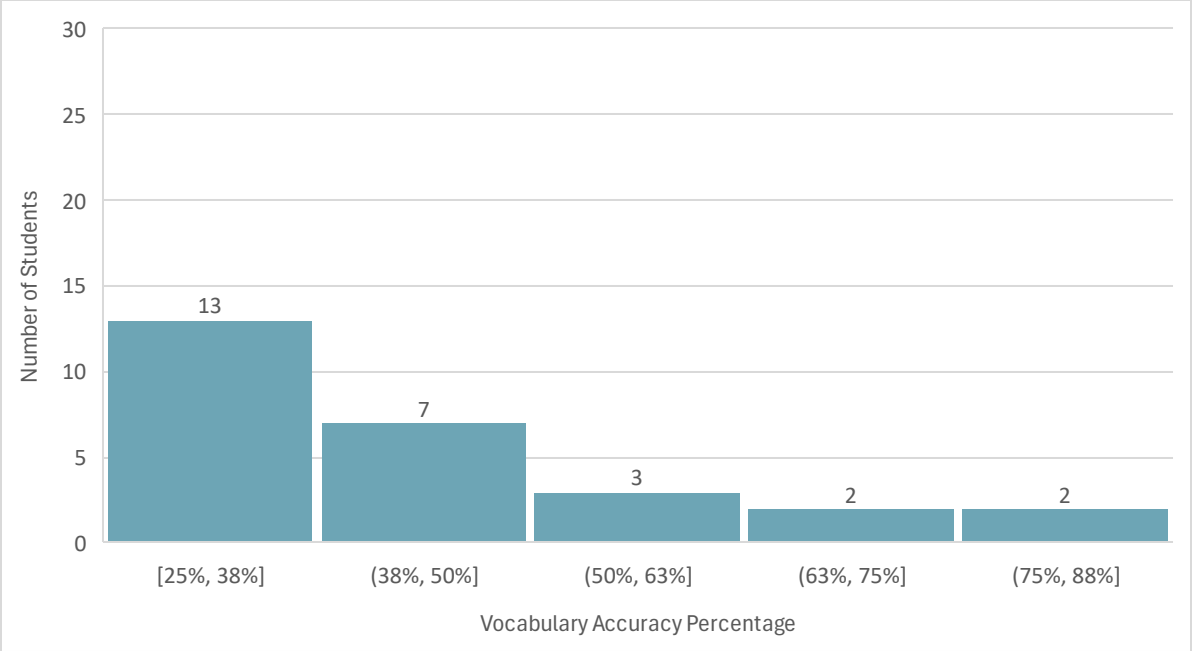


Figure 3. Pre-Assessment Probe Vocabulary Accuracy, (n=27).

This information indicates a weakness that indicated a lack in student comprehension about the water cycle. Review and identification of the terms selected or not selected by students highlighted more specific areas lacking comprehension and possible alternative conceptions. All the students identified rain as part of the water cycle, but only 74% identified precipitation as

part of the water cycle. Building on this discrepancy, only 48% identified snow as a water cycle element (Table 4).

Table 4. Pre-Assessment Probe Terminology Accuracy by Terms, (*n*=27). This data illustrates the accuracy in which students identified parts of the water cycle from a list of 20 key terms.

90-100%		70-89%	
Terms	**Accuracy**	**Terms**	**Accuracy**
Rain	100%	Freezing	89%
Condensation	96%	Cloud	85%
Water Vapor	96%	Evaporation	85%
River	93%	Precipitation	74%
50-69%		<50%	
Terms	**Accuracy**	**Terms**	**Accuracy**
Plants	67%	Snow	48%
Liquid Water	63%	Ocean	44%
Melting	63%	Surface Runoff	44%
Lake	56%	Glacier	41%
Transpiration	52%	Soil	37%
		Ice	33%
		Infiltration	33%

This information identifies two alternative conceptions – what precipitation is and what are the forms of precipitation. It also brings to awareness the lack of understanding of the meaning of key terminology. Almost all the students' responses identified rivers and rain as part of the water cycle. However, melting and sources of liquid water in the liquid state such as lakes and ocean were identified at a lower percentage. Additionally, almost all the students indicated that freezing played a role in the water cycle, but less than half selected the solid or frozen forms of water -- snow, glacier, and ice as playing a role in the water cycle. This hints at additional alternative

conceptions – the states of matter of water and the processes that change water's states. It also highlights another comprehension weakness between glaciers and ice and the understanding that glaciers are ice.

Additional alternative conceptions include understanding the roles of the ocean, soil, and plants in the water cycle. A minority of students selected ocean, soil, and surface runoff. Over half of the students identified plants as playing a role in the water cycle, but not as many students selected the term transpiration. This discrepancy indicates a lack in terminology knowledge. All these alternative conceptions and lack of comprehension are echoed in the other sections of the Pre-Assessment Probe, the sketches, and student explanations.

Water Cycle Sketches

Students' sketches in the Pre-Assessment Probe were graded on a five-point scale (Table 2). Scoring was based on a student's ability to create a sketch that reflected sound understanding of the water cycle and contained at least seven elements. Sketch responses that met this expectation were scored a 5. Comparable to the findings regarding the students' understanding of key vocabulary terms, data results from the rubric scores for the water cycle sketch showed weakness in comprehension and highlighted additional alternative conceptions held by students. The average rubric score was 2.8. A score of 2 indicated the sketch lacked representational qualities but had some identifiable water cycle elements or responded with diagrams rather than sketches. As shown in Figure 4, the highest percentage of students scored a 2 for their water cycle sketches according to the rubric used (Table 2).

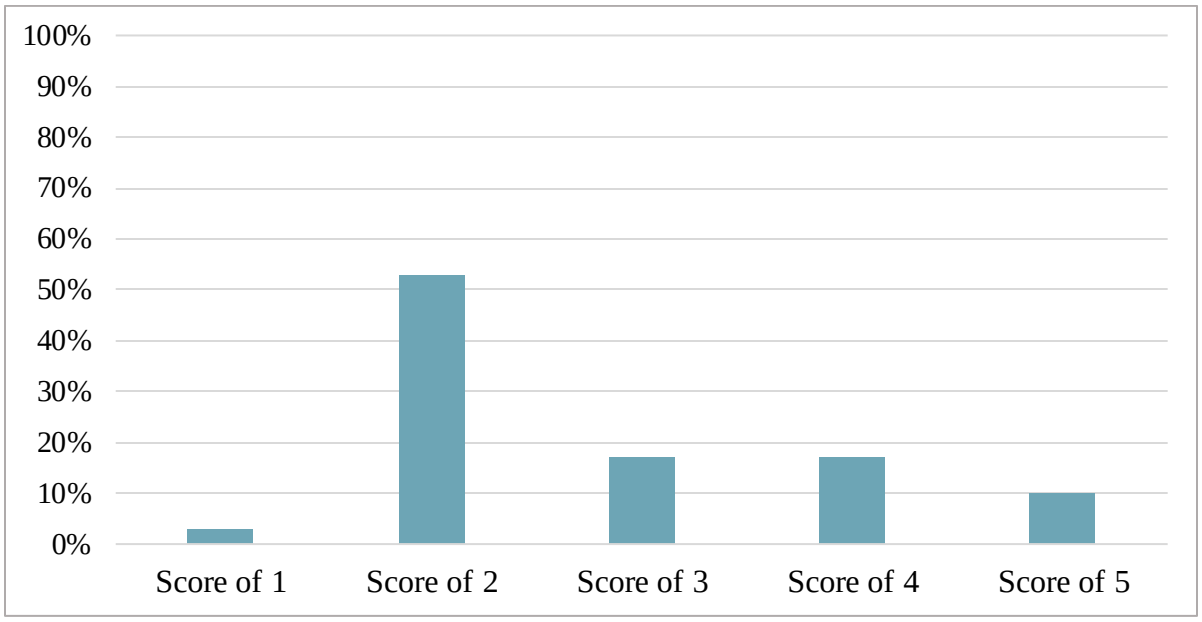


Figure 4. Pre-Assessment Probe Rubric Scores for Water Cycle Sketches, (*N*=30). The results illustrate the division of students across the various rubric score categories.

Sketches that scored a 3 or 4 on the rubric scale had visible misconceptions or contained only some elements of the water cycle and alluded to a lack in student comprehension and the presence of alternative conceptions regarding the water cycle. The remaining scores were on opposite ends of the rubric scale with a score of a 1 revealing no understanding of the water cycle. A small percentage of students demonstrated an understanding of the water cycle and its elements although each had less than ten elements included in the sketches. Their knowledge could be built upon their sound foundation of understanding and further expanded.

In addition to most of the students being unable to create a sketch of the water cycle to demonstrate an understanding of the process, multiple alternative conceptions were identified. Using student created sketches like the one shown in Figure 4, several additional alternative conceptions were identified. In Figure 5, two alternative conceptions were identified in the student's sketch.

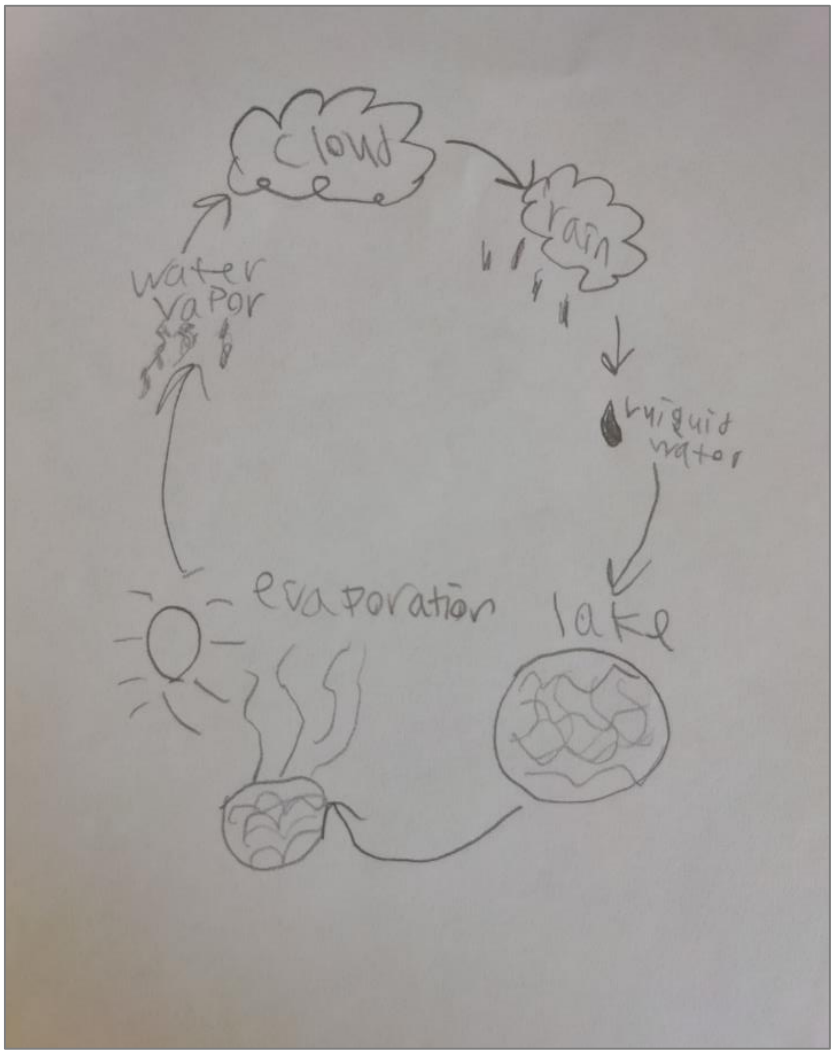


Figure 5. Pre-Assessment Probe Student Water Cycle Sketch.

One, the water cycle repeats the same movement of water or fluxes in a repetitive pattern with no variation. In the explanation of their water cycle sketch, the student explained the process in these words: “it rains makes water vaper then it makes cloud then the cloud rains then over and over and over and over and over and over again.” Another student explained that the water cycle “goes in circles,” indicating this alternative conception was held by multiple students. The second alternative misconception shown in the student’s sketch was that the water cycle is only made up of commonly known pools and fluxes such as evaporation, clouds, rain, and lakes.

These two misunderstandings of the water cycle were not the only alternative conceptions held by the students.

Additional alternative conceptions were identified in the students' explanations of the water cycle process. One alternative conception is that water vapor makes a cloud as illustrated in these student responses – "it rains makes water vaper then it makes cloud ..." and "water vapor forms clouds." Additional alternative conceptions were identified in the following student response: "First, the water becomes water vapor. Then it condensates and evaporates. Precipitation occurs and a cloud forms. It eventually rains and the water cycle repeats." In addition to believing the water cycle is a limited, repetitive pattern, the student exhibited several misunderstandings -- the changes in the states of matter, what precipitation is, the role of the sun in the water cycle, and the order of processes such as the formation of clouds and precipitation. The identification of these and other alternative conceptions within students' explanations of the water cycle process expose the need for targeted interventions and treatment to be implemented in the conceptual change process.

Student Confidence in Knowledge

Students' confidence in their understanding of the water cycle appears to be influenced by their inability to grasp key terms and their perceived difficulty in creating a visual representation, despite being unaware of their alternative conceptions. To evaluate changes in student confidence, if any, in their knowledge of the water cycle, a self-rated confidence survey was given to students as part of their Pre-Assessment Probe (Appendix B). As displayed in Figure 6, the findings from this survey indicated that students overall were not completely confident in their knowledge of the water cycle.

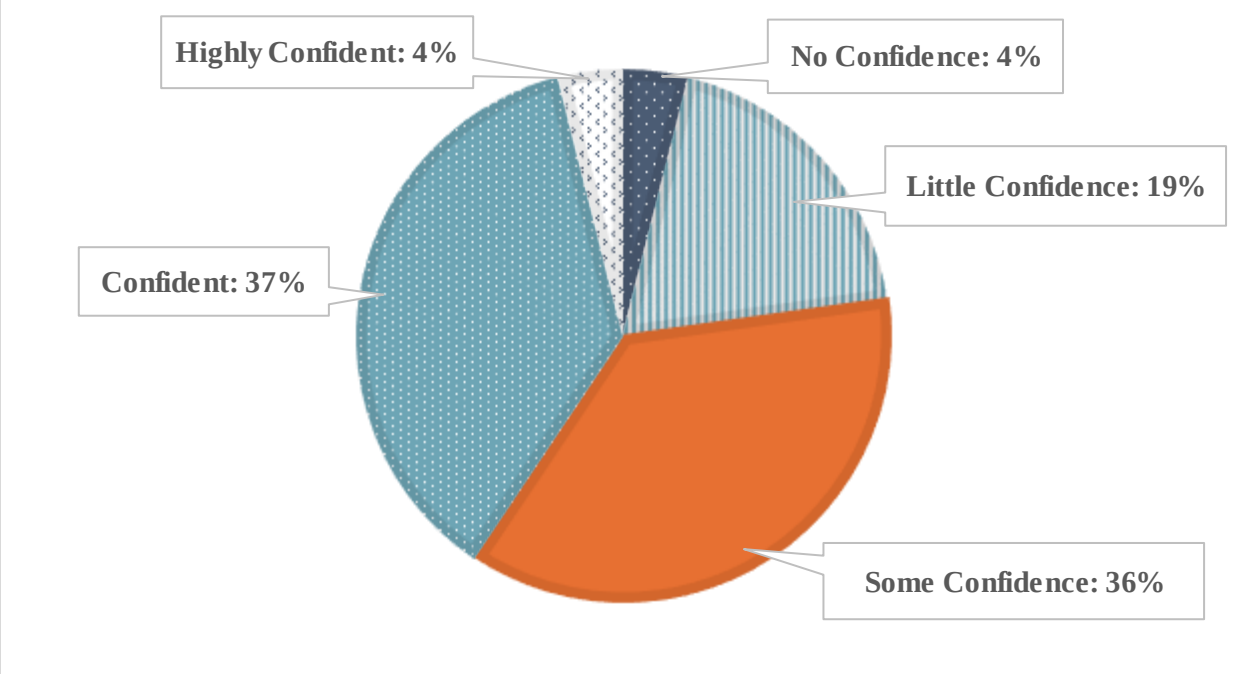


Figure 6. Pre-Assessment Probe Self-rated Student Confidence Percentages, (*n*=27).

Of the analyzed responses, most of the students were not completely confident in their knowledge of which 23% had little to no confidence. Thirty-seven percent of the students felt they were confident in their knowledge of the water cycle while only 4% of the students felt highly confident.

As part of the self-rated confidence survey, students were asked to explain their reasoning for their confidence rating. Students who rated themselves as confident or highly confident explained that they had learned about the water cycle in previous grades. One student who selected highly confident responded, “Because We learned this already.” A couple of students who rated themselves confident responded with “I feel like I remember the water cycle” and “I feel like I know about the water cycle because we learned some of it last yeas [sic] and I remember most of it.” Students who felt some confidence shared that “I feel I now [sic] some of the water cycle but I have I lot to learn” and “I knon [sic] the steps but not all of the words

correctly and I dont [sic] kow [sic] if I put them in the right spots." Students who felt little to no confidence in their knowledge of the water cycle expressed that they "have no idea what im talking about, kinda forgot" and "i don't remember anything about it." With the information and data gathered from the Pre-Assessment Probe, a plan was created for the conceptual change process to address the various alternative conceptions and lacks in understanding. All these areas – student understanding of associated vocabulary, student created water cycle sketch, and student confidence in their knowledge of the water cycle – were reassessed at the end of the unit using the same analysis tool for the Post-Assessment Probe.

Impacts on Student Comprehension

During the conceptual change process students were informally assessed with exit tickets, reflection interviews, and coded concept maps to identify any changes in their comprehension and confidence in their knowledge about the water cycle. This continued influx of information helped modify the conceptual change process as needed to determine how implementing the conceptual change process would affect student comprehension and confidence. Review of the terminology accuracy results from the Pre-Assessment Probe indicated vernacular misconceptions. The targeted conceptual change process was designed to first address these alternative conceptions and introduce students to key terminology associated with the water cycle. Throughout the conceptual change process, students were assessed to discover any effect it might have on their comprehension and confidence. One example used to evaluate student comprehension and any continued confusion was a Water Cycle Exit Ticket. This exit ticket was administered as a checkpoint and asked students "Which parts do you still feel confused about?". A review of student responses (Appendix F) listed lingering confusion about transpiration, infiltration, and state of matters among others. Even with these confusions the number of

students who could not identify at least half of the key terminology dropped significantly, from 67% to 11%. While most students could not identify at least 80% of the associated terms, the change in student comprehension is significant as supported by a calculated p-value <0.05. Figure 7 showed that when the number of accurately identified terms in the Pre- and Post-Assessments were compared, on average students were able to identify five more key terms on the Post-Assessment Probe.

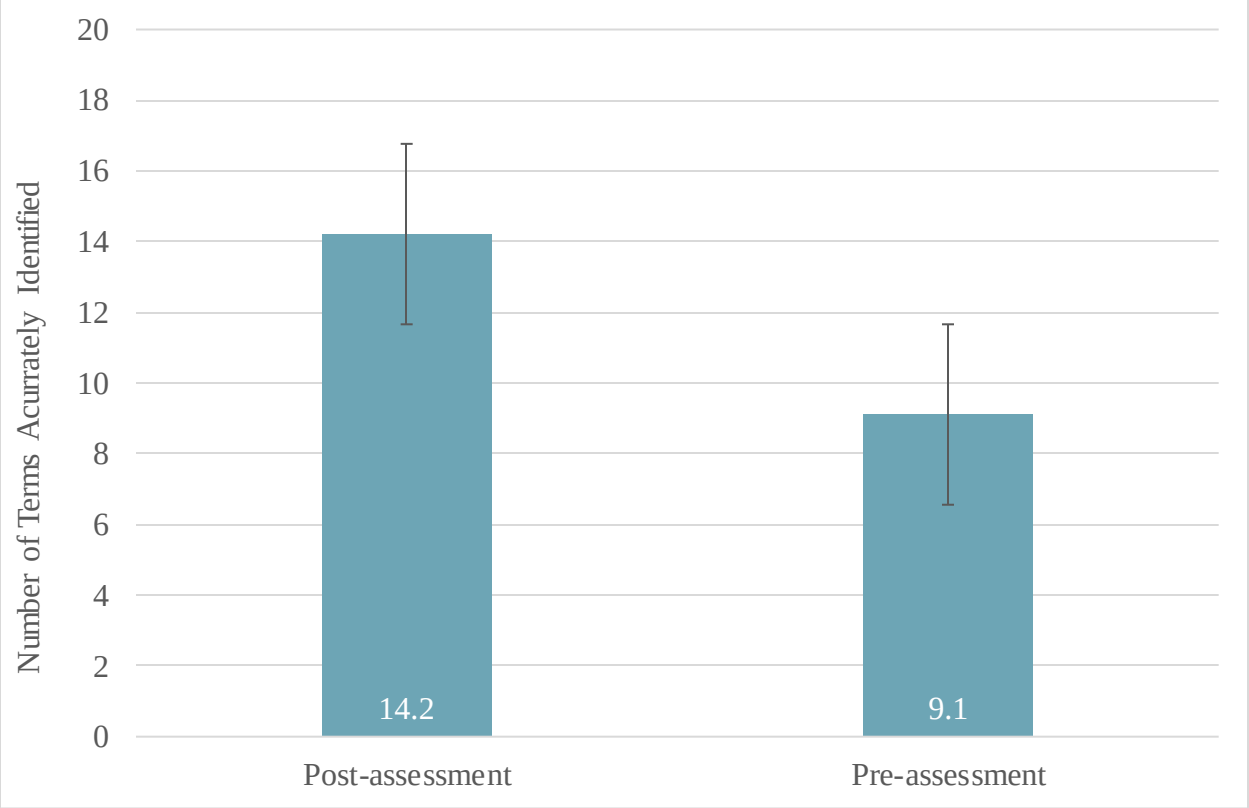


Figure 7. Pre- and Post-Assessment Terminology Result Comparison. The number of terms that were accurately identified were compared between the two end point probe assessments.

In addition to improvement in students' vernacular comprehension, students' ability to create water cycle sketches also improved. In Figure 8, a comparison of the rubric scores between both assessment probes shows changes in student performance. There was a decrease of

students who earned a score of 2 on their water cycle sketch and positive shift in how many students scored at least a 4.

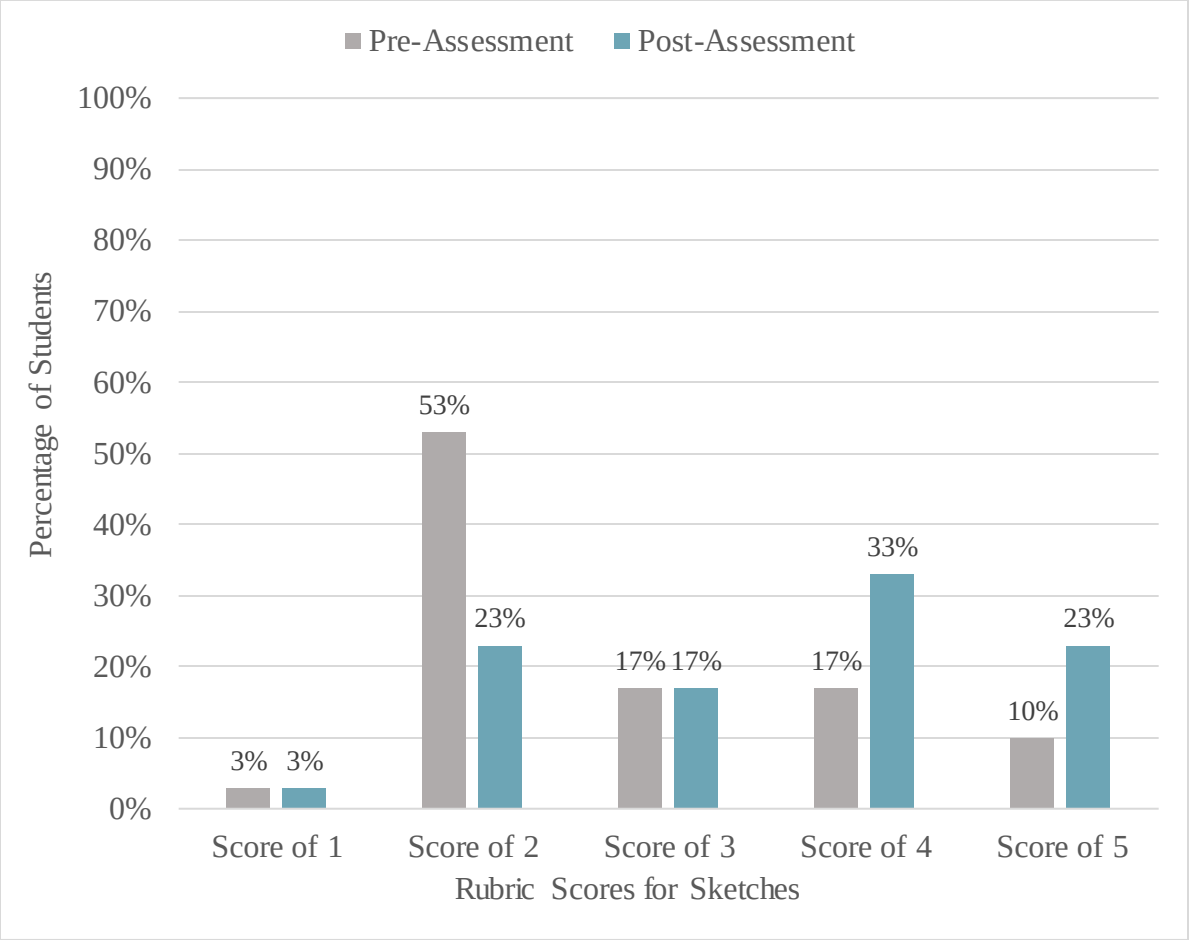


Figure 8. Comparison of Pre- and Post-Assessment Rubric Scores, (N=30). Student created water cycle sketches were assessed based on a five-point rubric.

While more students displayed an ability to create a comprehensive sketch of the water, an equal percentage of students could not and held alternative conceptions about how the different components of the water cycle worked together. While the data shown in Figure 9 supports growth in student comprehension of the water cycle, the change in rubric scores from the Pre-Assessment Probe to the Post-Assessment Probe was not significant.

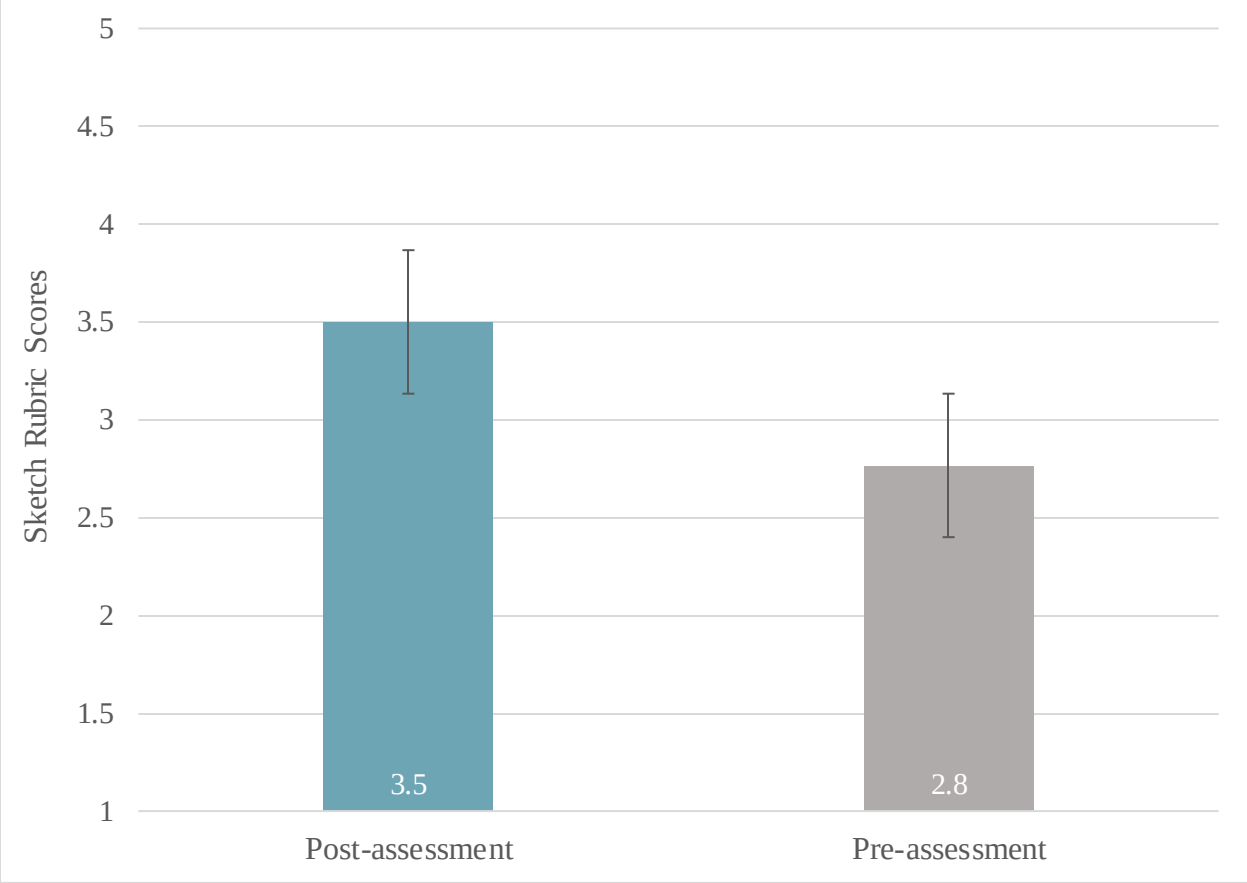


Figure 9. Comparison of Average Sketch Rubric Scores between Assessment Probes, (N=30).

The conceptual change process did have a positive impact on student comprehension, and in the case of the students' vernacular comprehension it was a significant change.

Impacts on Student Confidence

Building on the analysis of student comprehension, the examination of student confidence revealed a progressive trend across multiple assessment points. While student confusion persisted, when compared with student confidence ratings from four sources -- the Pre-Assessment Probe, two confidence surveys in exit tickets, and the Post-Assessment Probe -- student confidence steadily increased over the course of the conceptual change process. The increase in student confidence was notable from the beginning of the conceptual change process to the end. As previously shown in the Pre-Assessment Probe confidence survey, 23% of the students responded that they felt little to no confidence in their knowledge of the water cycle. As shown in Figure 10, the percentage of students who rated themselves as having some to no confidence decreased to 0%.

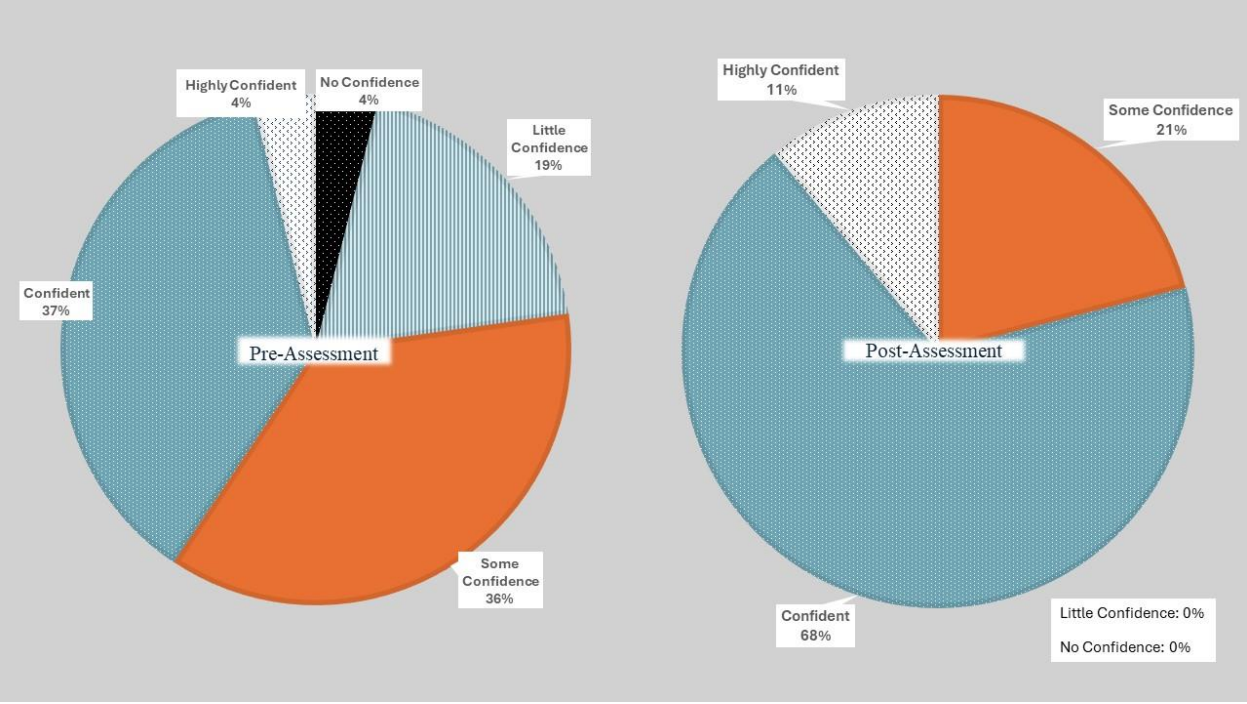


Figure 10. Pre- and Post-Assessment Probe Self-Rated Confidence Percentages, (*n*=28).

Although 21% of students only felt some confidence in their understanding of the water cycle in the Post-Assessment confidence survey, this is a decrease in the number of students who felt this way on the Pre-Assessment Probe survey. Additionally, Figure 11 highlights the difference students felt in confidence between the two probes.

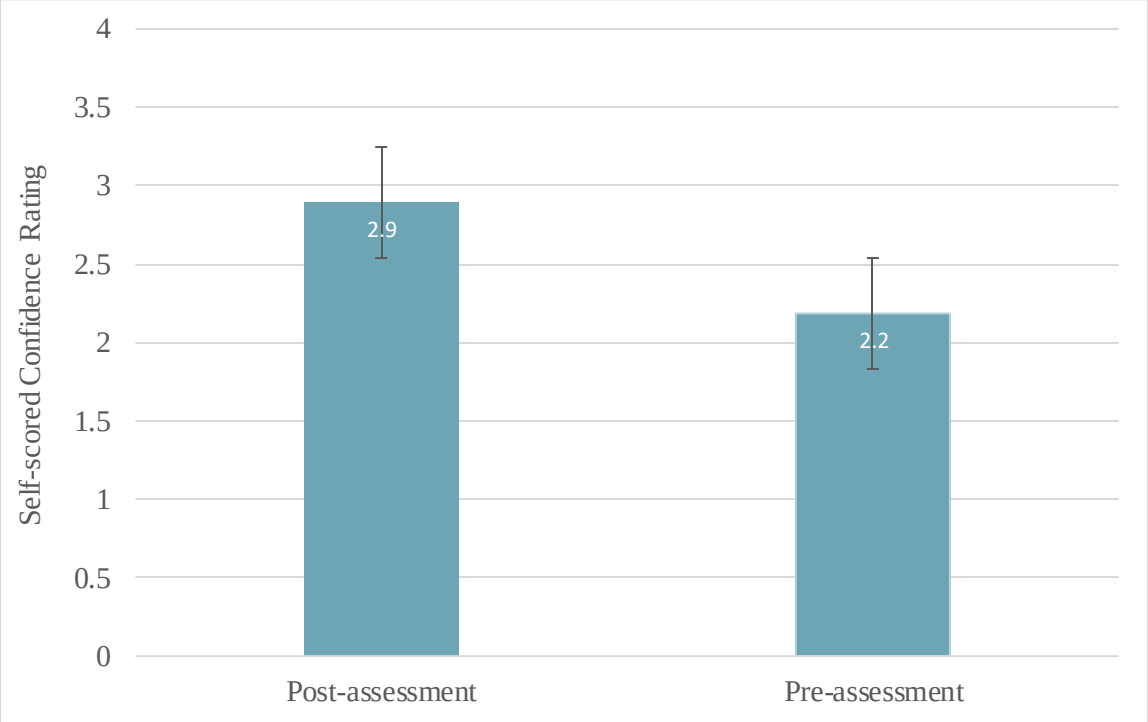


Figure 11. Student Confidence Level Comparison between Assessment Probes.

The average confidence rating in the Pre-Assessment Probe was 2.2 while the average confidence rating on the Post-Assessment Probe was 2.9. With a p-value <0.05, this highlights a significant change in students who now felt confident or highly confident indicating confidence in content knowledge is impacted by a strategic conceptual change process.

CHAPTER FIVE
CLAIM EVIDENCE AND REASONING

Within this chapter, insights on the impact, if any, of the conceptual change process on student comprehension and confidence are presented. These insights and claims were made based on the synthesis of a collection of qualitative and quantitative data before, during, and at the end of the conceptual change process. Addressed are claims regarding student comprehension and confidence as well as the value of the study, considerations for further study, and the impact of this research study on the author.

Claims From the Study

The impact of the conceptual change process on student comprehension and confidence were evident through research and data analysis. By implementing strategic interventions, this study observed improvement in both student understanding and confidence levels from the pre-assessment to post-assessment stages. Notably, students demonstrated improved accuracy in terminology and proficiency in integrating concepts as shown by their ability to create comprehensive sketches of the water cycle. Additionally, self-assessed confidence ratings significantly increased among students, correlating closely with their improved comprehension of the subject matter. The subsequent claims in this chapter demonstrate how active engagement in the conceptual change process fosters deeper understanding and greater confidence among students.

Impact of Conceptual Change on Student Comprehension and Confidence

A strategically implemented conceptual change process positively affects student comprehension and confidence. Keeley (2016) stated that techniques that "engage students in thinking about their ideas in science, uncover preexisting ideas students have that can be used as starting points to connect with new concepts" which helps both students and teachers in the learning process (pp. 3-4). Using both a pre- and post-assessment probe allowed students' alternative conceptions to be uncovered, a conceptual plan to be developed, and any changes in student comprehension to be tracked. When comparing students' responses on the Pre-Assessment and Post-Assessment Probes used in this research, a marked increase was observed in both student comprehension and confidence. The number of students who exhibited both terminology accuracy and demonstrated the ability to create a sketch of the water cycle incorporating seven or more elements increased. The self-scored student confidence ratings of confident or highly confident also increased. This increase in the number of students who felt more confident in their content knowledge correlated with the increase in understanding of the water cycle, showing the impact the conceptual change process has both on student comprehension and confidence.

Impact of the Conceptual Change Process on Student Comprehension

Students' active involvement and engagement in the conceptual change process enhanced students' understanding of the content. The identification of alternative conceptions and gaps in student understanding as shown in the Pre-Assessment Probe provided information needed in developing a targeted treatment plan. Again, referencing The National Research Council (1997), before students must be allowed to confront their own beliefs and conceptions before they can build upon it with new knowledge (p. 29). Activities such as exploration stations,

discussions, argumentative writing (claim-evidence-reasoning statements), and reflective interviews were implemented and encouraged students to confront their existing ideas. Keeley (2012) pointed out that "is important to provide instructional experiences that will confront student thinking and guide them" (p. 13). The ability of students to create connections to current knowledge and develop new understandings allowed them to shape their own understanding and conceptions. Through this targeted process students refined their understanding and conceptions of the content and saw growth in their comprehension.

Impact of Conceptual Change Process on Student Confidence

Engagement in the conceptual change process significantly enhances students' confidence in their content knowledge. On the NCFE.org website, Gill (n.d.) shared that "studies have shown that learners with higher confidence are more willing to learn, challenge themselves, and have better resilience …. confidence has long-term, positive effects on learners' success." During the conceptual change process students' confidence improved as they were actively engaged in the learning process. Through tools such as the Pre-assessment Probe, Exit Tickets, and explorative, student-led activities, students shared their understandings and confusions with their peers and instructor. While this approach exposed areas of confusion and alternative conceptions among students, by confronting their existing understanding and constructing personal conceptions through these student-led experiences, students took ownership of their learning. By deepening their understanding students also bolstered their confidence in their knowledge.

Value of the Study and Consideration for Future Research

The overall growth and positive change in both student comprehension and confidence indicates the importance of a targeted conceptual change process. Alternative conceptions held by students must be identified in order to develop a targeted learning process that engages the students in active learning. I was able to see why Keeley (2012) said it was important to provide instructional experiences to guide students through learning experiences rather than force changes in students' thinking (p. 13). When students were given the freedom to explore and confront their own beliefs and conceptions and connect that new knowledge to what they already knew in a Velcro moment like Heal (2023) described. When I understood what the students' weaknesses in comprehension were, I was able to select a variety of exploration stations that allowed students to ask questions, make connections, and begin to confront their own misconceptions. When it was shown that students did not understand the roles of soil, infiltration, and groundwater in the water cycle, an exploration station was created to allow students to observe infiltration (Figure 12), including how quickly water moved through a variety of substances (i.e. sand, dirt, gravel). At the conclusion of the study, 89% of students demonstrated an understanding of infiltration's role in the water cycle on the Post-Assessment Probe, compared to just 33% at the start of the unit. An awareness of students' weaknesses in comprehension and their alternative conceptions allowed me to address these in a more efficient, more engaging manner resulting in positive student outcomes.



Figure 12. Image of Infiltration Exploration Station. This station was used early in the conceptual change process and later to build upon student understanding.

Both the literature reviewed during research planning and the data collected during its execution underscore the significance of active, student-driven learning. Consequently, I have developed an interest in exploring how students' mindset affects engagement, comprehension, and confidence. In a future study, I would like to explore how student mindset influences their capacity to confront alternative conceptions and participate in student-led learning.

Impact of Action Research on the Author

Upon reflection, I am reminded of how my action research study evolved from my exposure to misconception probes, exploration stations, and student-led learning in the MSSE program. Through this project, I witnessed firsthand the profound impact of student-led inquiry. Observing my students during the exploration stations, I felt an unmistakable sense of their

excitement and curiosity, resonating with my own experiences as a student. Just as they had their 'aha' moments, so did I. As I reviewed the growth in my students' confidence, I couldn't help but recognize a similar growth within myself as an educator and a learner. The excitement I felt as I learned ways to make a positive impact on my students' learning was mirrored in their engagement and excitement to learn about the natural world.

I felt the most striking outcome of this research was witnessing that deep engagement of my students during the exploration stations. Originally planned for one day, they unexpectedly extended to two due to the students' enthusiastic participation. The impromptu discussions and witnessed connections being made, illuminating moments of insight such as, "That is why that happens when I take a hot shower!" showed excitement and connection between the lessons of the classroom and students' life experiences. The same student's CER statement about evaporation reflects a growing understanding of the process.

> My claim is that the water plays an important roll [sic] in the water cycle here's why when its [sic] at a certain temperature it evaporates and goes into the atmosphere and condensates which makes clouds and here's my evidence when your [sic] in the shower and the water is hot when you get out the mirror in the shower has fog and that's because the hot steam is touching the cold shower mirror and the hot water sticks to it.

While some incorrect conceptions linger, the student was able to build upon her knowledge and experiences to confront and support that knowledge with facts.

From this I recognized the necessity for students to not only share but document their thoughts, impressions, and questions post-activity. This documentation aided in gauging their comprehension and enhanced my understanding of their grasp on the content. I came to appreciate the significance of monitoring students' confidence levels throughout the learning process. Assessments such as exit tickets combined with confidence surveys emerged as a simple

yet powerful tool, offering valuable insights into my students' learning journey. Through my action research study, I was able to observe the impact certain instructional strategies can have on student comprehension and confidence as well as the importance of consistent formative assessments to document that change.

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APPENDICES

APPENDIX A

IRB APPROVAL

Hello Pincock, Carolyn,

Your protocol was reviewed by the IRB and has been approved.

PI: Pincock, Carolyn
Approval Date: 2/12/2024
Title: The Impact of Conceptual Change on Student Alternative Conceptions and Confidence

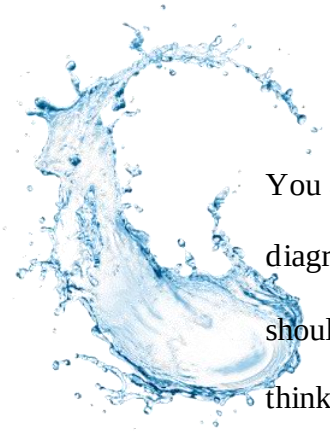
Protocol #: 2024-1197-EXEMPT
Review Type: Exemption
Expiration Date: 2/12/2029

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

APPENDIX B

PRE AND POST ASSESSMENT PROBE

Name: _____ Class: _____ Date: _____



The Water Cycle

You are part of a small group of students working together to draw a diagram of the water cycle. Each of you has different ideas for what should be included in the diagram. Place a ✓ next to the things that you think are part of the water cycle.

- ☐ Cloud
- ☐ Condensation
- ☐ Evaporation
- ☐ Freezing
- ☐ Glacier
- ☐ Groundwater
- ☐ Ice
- ☐ Infiltration
- ☐ Lake
- ☐ Liquid Water
- ☐ Melting
- ☐ Ocean
- ☐ Plants
- ☐ Precipitation
- ☐ Rain
- ☐ River
- ☐ Snow
- ☐ Soil
- ☐ Surface runoff
- ☐ Transpiration
- ☐ Water Vapor

In the space below, draw a diagram of the water cycle using your selected items.

Based on your diagram of the water cycle above, explain the water cycle process.

APPENDIX C

EXIT TICKETS

CONCEPT FOCUSED QUESTIONS

- Explain the process of evaporation.
- Name examples of precipitation.
- How does condensation play a role in cloud formation?
- Define transpiration.
- Explain why the water cycle is a closed system.
- Compare and contrast condensation and evaporation.
- Explain how the hydrosphere and geosphere interact during the water cycle.
- Explain the sun's role in the water cycle.
- How does gravity play a role in the water cycle?
- Create a CER statement about pool and fluxes.
- What parts of the water cycle do you understand better?
- What still confuses you about the water cycle?

SELF-SCORING STUDENT CONFIDENCE SCALE

How confident are you with your answer?				
No confidence 0	Little Confidence 1	Some Confidence 2	Confidence 3	High Confidence 4
Explain the reason for your choice.				

APPENDIX D

INTERVIEW SAMPLE QUESTIONS

INTERVIEW QUESTION EXAMPLES

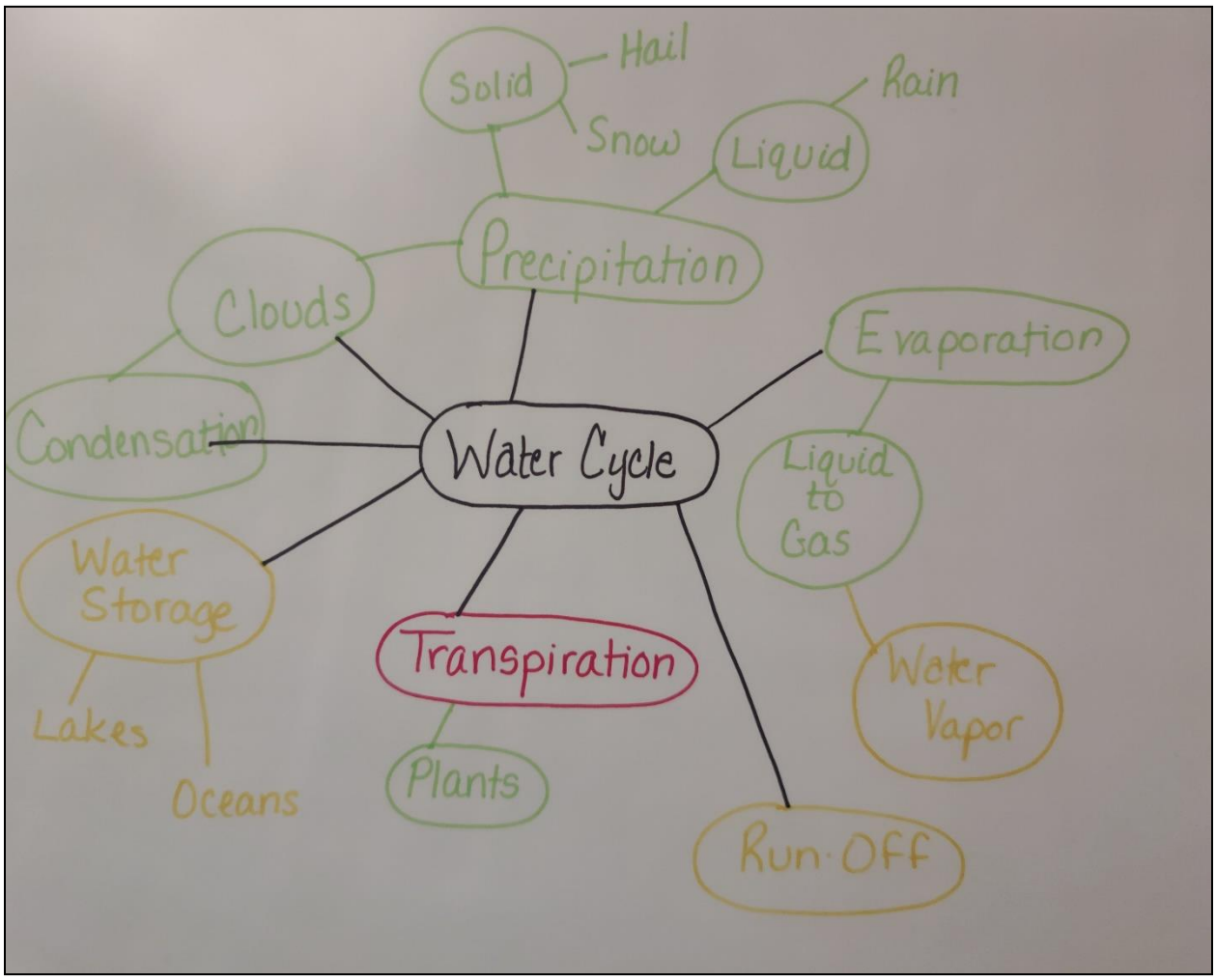
- How has (instructional activity) helped you understand the water cycle?
- How would you explain the water cycle to a friend?
- What do you understand now that you did not before completing the activity?
- What muddy points (confusions and/or challenges) do you have?
    - Are these new muddy points or ones you already had?
- Do you feel more confident or less confident with your knowledge of the water cycle?
    - Please explain your choice.

SELF-SCORING STUDENT CONFIDENCE SCALE

How confident are you with your answer?				
No confidence 0	Little Confidence 1	Some Confidence 2	Confidence 3	High Confidence 4
Explain the reason for your choice.				

APPENDIX E

CODED CONCEPT MAP


Water Cycle
Precipitation
Solid
Hail
Snow
Liquid
Rain
Clouds
Condensation
Evaporation
Liquid to Gas
Water Vapor
Water Storage
Lakes
Oceans
Transpiration
Plants
Run-Off

APPENDIX F

DATA ANALYSIS TABLES AND GRAPHS

Table 5. Water Cycle Exit Ticket Student Responses, (*n*=27). Quotes from student exit ticket responses regarding what parts of the water cycle are confusing from a list of 20 key terms.

Which parts do you still feel confused about?
Groundwater and Transpiration
im [sic] still a little confused of what transpiration is but i know its in the water cycle
Infiltration I need a little more work on.
I feel a bit confused on how freezing is caused, and how glaciers and ice are caused
Glaciers and ice
infiltration because i stil dont [sic] understand it that much
Freezing, Melting, Glaiciers [sic] and Ice
water vapor , infiltration [sic]
I still feel confused about Condensation, Glaciers and Ice, Surface Runoff, and Transpiration.
clouds because i feel like its not really cliking [sic] for me yet.
water vapor and everything i didnt [sic] pick
metling [sic] and freezing
Infilration [sic], Groundwater, Transpiration
what does freezing have to do with the water cycle
Evaporation from the ground
does the evaporation from the ground just rise up that easily