

THE IMPACTS OF TEACHING THE CROSSCUTTING CONCEPTS IN A
PROFICIENCY-BASED SYSTEM

by

Christine DeLeo Fitch

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ABSTRACT

Education in the State of Vermont is evolving due to new legislation. By 2020, our students must graduate from a proficiency-based system. Vermont students must demonstrate proficiency in science in order to meet graduation requirements. Based on the Next Generation Science Standards (NGSS), students are considered proficient in science when they master the science and engineering practices (SEP), cross-cutting concepts (CCC), and disciplinary core ideas (DCI) which are outlined in the framework.

The purpose of this research is to assess student proficiency in CCC in regard to the intervention of implementing CCC learning progressions. The treatment was applied in a ninth-grade earth science class over the course of a 6 week long unit. The sample size was approximately 52 students. The treatment included activities that articulated examples of CCC and a learning progression that aided in the delivery of CCC throughout the unit. The progression was used by the teacher to drive activities and score assessment, as well as, by the students as a path towards proficiency. DCI and SEP were taught concurrently with the CCC using current practices.

The results indicate that there was no improvement over the treatment period in regards to students' ability to apply the CCC to the DCI. There was no distinction made between student scores on the pre-treatment unit assessment and the post treatment unit assessment. However, a small association was found between explicit teaching of the CCC and student understanding of the DCI.

INTRODUCTION AND BACKGROUND

East Montpelier is a town located in central Vermont. U-32 High School is a public school serving the residents of East Montpelier and surrounding towns that compose the Washington Central Supervisory Union. U-32 High School has 749 students in grades 7 through 12. A middle school program for seventh and eighth graders is in the same building as the high school. According to the State Agency of Education's school report, 24% of the U-32 students are on free or reduced lunch. From the same report, 93% of the students are white, 2% Asian, 2% Black, 1% are Hispanic, and 1% are multi-racial (Vermont Agency of Education, 2017).

I used my ninth-grade earth science course for the purpose of this classroom research project. There were three sections for this course. While the course was set up for ninth-graders, some eighth graders opted to take this course in addition to their middle school science class. Tenth graders were required to take the course to gain proficiencies missed the year before. Aside from differing grade levels, the sections were composed of students with a range of science abilities. The first section was composed of 17 ninth graders and 1 tenth grader. Four of the students in this section were on individualized education plans (IEPs) and/or 504s. The second section was composed of 6 eighth graders, and 13 ninth graders. Five of the students in this section were on IEPs and/or 504s. The third section was composed of 15 ninth graders. Four students from this section were on IEPs and 504s.

Education in the state of Vermont is evolving. By 2020, students must graduate from a proficiency-based system, requiring teachers to adjust their teaching methods and

administration to adjust their reporting. Many in the education world find this daunting. However, I, along with many of my colleagues, am excited about the shift and foresee benefits for our students and teachers.

Proficiency in science at U-32 is based on the Next Generation Science Standards (NGSS). The expectation for students in our science classes is that they continue to learn the disciplinary core ideas (DCI), while simultaneously developing the science and engineering skills (SEP) to be a scientist. A goal for the students in my Earth science course is that they will understand Earth's internal and external processes that create geologic products. The students will also be able to model those processes to demonstrate their understanding. While students are learning the DCI and SEP, NGSS suggests teaching students crosscutting concepts. The CCC are themes that transcend all science classes; such as identifying patterns or cause and effect relationships. NGSS has labeled the simultaneous teaching of DCI, SEP, and CCC as three-dimensional (3D) learning.

Understanding how teaching the CCC effects students' understanding of the DCI would be beneficial both as our teaching evolves three dimensionally and as our state requires us to voyage into proficiency-based teaching. I've selected to investigate the following problem statement in my classroom research project: Does explicit instruction around cross-cutting concepts paired with proficiency grading have an impact on student mastery of content? My secondary question: Does explicit instruction around cross-cutting concepts paired with proficiency grading have impact on student confidence?

CONCEPTUAL FRAMEWORK

Assessment in a science class has many purposes when used for feedback for teachers and students. Teachers can use assessment to determine the level of student comprehension. Students can use assessments to provide evidence of their understanding. Teachers and students can use assessment to determine what remains to be learned. The literature exhibited here attempts to address the question of a student's ability to learn in a three-dimensional manner and determine what criteria are needed to assess a student's proficiency in science.

The move toward proficiency-based learning by many states across the nation has the opportunity to make assessment in the classroom more informative for teachers and students. The Vermont State Board of Education approved the Education Quality Standards (2014), which states that students graduating in 2020 must demonstrate proficiency in the school's graduation requirements. Graduation requirements must be identified by the school in literacy, math, science, global citizenship, physical education and health, artistic expression, and transferrable skills. Use of credits to track proficiencies is optional. However, credits can no longer be defined by the hours spent in a class but defined by the proficiencies taught during that class. Proficiency-based graduation is defined by the Agency of Education in the Series 2000 – Education Quality Standards as the

systems of instruction, assessment, grading, and academic reporting that are based on students demonstrating mastery of the knowledge and skills they are expected to learn before they progress to the next lesson, get promoted to the next grade level, or receive a diploma (2014, p. 3).

Vermont students must demonstrate proficiency in the science proficiency-based graduation requirements which are aligned with the Next Generation Science Standards (NGSS) (Series 2000 - Education Quality Standards, 2014).

Meeting proficiency is organized by the U-32 science department as seven standards, some of which are related to the NGSS crosscutting concepts (CCC). Falling under those standards are two to seven performance indicators which are closely related to the NGSS DCI and SEP. A student needs to demonstrate proficiency in a specified number of performance indicators for each of the seven standards over their high school career. During the Earth science course, students are asked to demonstrate proficiency in three of the seven standards. The students will interact with these three standards as well as the remaining four throughout their high school career.

NGSS were created to address the insufficient scientific knowledge and scientific ability of our students (National Research Council, 2012). The hope is for our nation's students to be able to think and act like scientists. The framework outlines three dimensions (3D) of science learning: science and engineering practices (SEP), crosscutting concepts (CCC), and disciplinary core ideas (DCI). The curriculum, lessons, and assessments are meant to be designed for students to "actively engage in science and engineering practices in order to deepen their understanding of cross-cutting concepts and disciplinary core ideas" (National Research Council, 2012, p. 217). The intertwining of SEP, CCC, and DCI is considered 3D teaching. Students are considered proficient in science when they master the SEP, CCC, and DCI outlined in the framework.

In order to develop their skills in science and engineering, the students must develop a “deeper understanding” of the content they are studying (Schwarz et al., 2009). There are a number of examples of curricula intertwining DCI, CCC, and SEP to create a pathway to gain a deeper understanding. The DCI, CCC, and SEP are taught and developed by the student simultaneously.

DeBarger et al. (2017), Gotwals and Songer (2013), and Schwarz et al. (2009) found that when students apply scientific practices to scientific ideas they show that they can think and act like scientists. Students, when taught using the 3D teaching technique, succeeded in understanding SEP and DCI. This understanding develops over time. Linear progressions of student learning of the science content or practices help teachers guide student learning and develop assessments.

Studies, which will be discussed in further detail, have established that students are able to successfully learn and ultimately think like a scientist when moved through a three-dimensional (3D) curriculum. DeBarger, et al. (2017) found positive outcomes in the classrooms that used a science practice to apply content. Throughout the earth science units, the treatment classrooms participated in more “high-leverage talk” on average compared to the comparison classrooms. The treatment group had an overall higher average point difference than the comparison group, implying that students using science practice to apply content retain the science information better.

Schwarz et al. (2009) analyzed student change in both the understanding of the content and the actual practice of modeling. A unit was used in the elementary classes to move the students through the progression of learning how to model. The study found

that the student understanding of both DCI and SEP progressed throughout the unit. The students advanced to the point that they could model the more complex ideas about evaporation and condensation. “The students’ reasons for revising models seemed linked to gathering evidence and learning more about the phenomena, and indicated some steps toward seeing models as improving based on their ability to ‘show how’ or explain why phenomena occur” (Schwarz et al., 2009, p. 650). The results of the study by Schwarz et al. (2009) suggest that students are able to simultaneously advance in their knowledge of practices and science content.

A similar conclusion was found by incorporating the third NGSS dimension, CCC into a unit. In Fick’s (2018) study, students were able to demonstrate more developed SEP and a clearer understanding of the DCI. Fick worked with a teacher to develop 3D curriculum for a middle school science class that integrated the CCC, systems and system models, into a watershed unit that also involved the SEP of modeling. Her results “show that the students used the CCC to support their development of a three-dimensional of the concept of watersheds using implicitly integrated curriculum materials, classroom discussion, and opportunities to model the phenomenon” (Fick, 2018, p. 28).

This advancement in student knowledge of science can be mapped out. A learning progression is a breakdown of a DCI or a SEP and attempts to be in the sequence of how a student would learn the full concept or practice. Learning progressions are utilized to guide a students’ learning from their original thoughts to the targeted science content (Debarger et al., 2017). Elementary and middle school students progressed through a unit on modeling evaporation and condensation in the study completed by Schwarz et al.

(2009). The students' models advanced in complexity and in ability to depict that which is not visible. The learning progressions were used to evaluate the students' work.

Learning progressions direct teachers to create lessons that lead students through the course of learning and ultimately to an understanding of the intended DCI and SEP. Debarger et al. (2017) found that by outlining the elements that make up the intended concept ahead of time, teachers could guide students' original ideas to the science concept more efficiently. These progressions helped ensure that the lessons were aligned with the assessments. Pellegrino (2013) stated that "assessment should help determine where a student can be placed along a sequence of progressively more 'scientific' understandings of a given core idea that by definition includes successively more sophisticated applications of practices and cross-cutting concepts" (p. 320).

Gotwals & Songer (2013) offered insight in the creation of learning progressions. In their study on the effectiveness of 3D science assessments, the learning progression for the SEP was created separately from the learning progression for the DCI. Figure 1 outlines the learning progression for students writing an evidence-based explanation. The DCI progression was created for students that spanned grades four through six. A basic idea was defined for fourth grade and built in complexity through grade six. The learning progression for the SEP was also defined (p. 602).

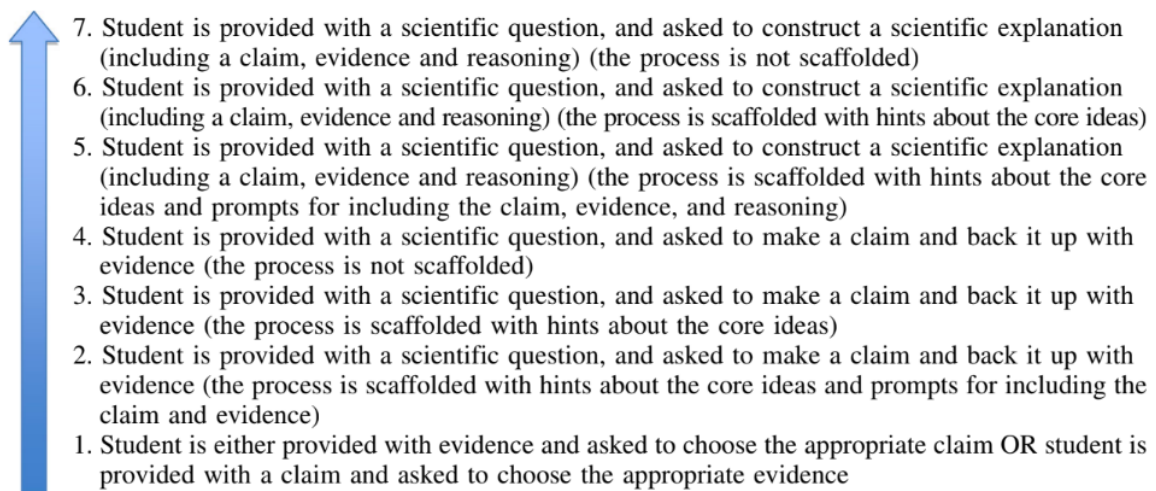


Figure 1. Learning progression from Gotwals & Songer (2013, p. 602).

Schwarz et al. (2009) found it challenging to pull apart the many skills needed for a student to become proficient at modeling when they were creating the learning progressions. Their study followed the student learning progression for the specific science and engineering practice of creating and using models. This one practice requires a number of smaller skills to be mastered before reaching proficiency. A teacher in the study by Toland and Gerstl-Pepin (2017) elaborated by saying that “the target was about the skills that were being taught and assessed and that there were no other skills masking the student’s ability to demonstrate it” (p. 72). Toland and Gerstl-Pepin (2017) quoted one of the teachers followed in the study to further explain this idea.

[The student is] good at figuring out evidence and piecing pieces together that support something but in the past we would have asked him to come up with a thesis and then with the evidence but he’s not at thinking level yet to come up with a good thesis so he comes up with a bad thesis and therefore you’re going to come up with bad evidence and you’re going to have a bad paper (p. 72).

Gotwals and Songer (2013) found in their study on students’ learning progression on the practice of constructing explanations that, while all students successfully

developed the skill of writing claims, the most challenging part of this skill was including the scientific reasoning to support the evidence. Pulling apart the practice and content is necessary in developing the learning progressions to make for a smooth experience for the students. However, Gotwals & Songer (2013) pointed out that while one learning progression may work, there is no reason why another progression might not also work for the students.

One challenge in using learning progression is that the learning experience may differ for students depending on age and ability. Older students' progressions are defined by "standards and societal expectations" (Gotwals & Songer, 2013, p. 599). Younger students' progressions are designed with "cognitive science research" in mind (Gotwals & Songer, 2013, p. 599). Another challenge in creating learning progressions identified by Gotwals and Songer is that younger students learn in different sequences from each other. This can make progressions hard to define when students take different paths in their development of understanding (Gotwals & Songer, 2013).

Gotwals & Songer (2013) studied 300 sixth graders from 3 different schools found that after the students finished the 3D curriculum, all students were deemed proficient in being able to write claims. Most of the students were deemed proficient in being able to support those claims with evidence. Some of these students used scaffolding techniques to assist them in using supporting evidence. The assessment used in this curriculum documented the varying ability of the students to perform the selected SEP in conjunction with the selected DCI.

Teachers can follow criteria to guide their creation of a 3D assessment as a way of addressing the complexity of such a task. Penuel, Van Horne, and Bell (2016) established a five-step process for creating a 3D assessment. The first step asks the teacher to draft a claim from more than one standard. In order to be considered 3D, the claim must assess the students understanding and ability of at least one DCI, SEP and CCC. DeBarger, Penuel, Harris, and Kennedy (2015) asked whether the assessment reliably measures the students' understanding of the claim to guide their assessment design. To ensure students are being assessed at their highest levels, Pellegrino (2013) advised that the DCI chosen for the assessment should be chosen from a NGSS that aligns with their age and level of understanding.

The second step outlined by Penuel et al. (2016) is for the teacher to choose a "central scenario" to base the multiple assessment questions around (p. 3). Once the theme is established, the teacher chooses multiple SEPs to use throughout the assessment. "Each scenario is likely to rely on multiple formats to develop specific questions for students to answer, because 3D tasks are multi-component tasks" (Penuel et al., 2016, p. 4).

Multiple questions should be posed that require students to provide responses that assess their understanding of the SEP (Penuel et al., 2016). These questions should be designed in such a way that the level of students' understanding of the DCI and ability to perform the SEP is documented. One of the features of proficiency-based assessments is that they are customized for students allowing them the flexibility to learn at their individual pace (Toland & Gerstl-Pepin, 2017). In order to do so, carefully drafted

questions are needed to provide insight about the student's level of understanding for the student and teacher. Pellegrino advises to take into consideration "the types of evidence that will reveal levels of student understanding and skill" (Pellegrino, 2013, p. 321).

The types and levels of evidence can be expounded during step four of the assessment tool created by Penuel et al. (2016). Potential student responses to the assessment questions are drafted. This allows the teacher to refine the central scenario and develop rubrics. The teacher uses rubrics to determine if the student met the claim and what their level of understanding is (Toland & Gerstl-Pepin, 2017).

The final step to Penuel et al. (2016) is to revise the assessment. The revision process can be aided by comments from colleagues and pilot tests. Both Pellegrino (2013) and Penuel et al. (2016) acknowledge the need for field testing assessments. Penuel et al. (2016) advise that by using more than one central theme, then the "multiple scenarios allows you to evaluate which ones are better for eliciting student understanding" (p. 3).

Over time, the student results of these assessments can help build a resource composed of additional lessons to target problem areas where students struggle with specific area of the content (Penuel et al., 2016). As students move through their progression of learning, it is important that the lesson is adjusted based on their current understanding. Additional activities should target specific scientific ideas or practices where students might get hung up on particular facets or challenging parts of the concept (Debarger et al., 2017).

A 3D assessment documents the students' proficiency in the unit's practices, core ideas and crosscutting concepts. Assessments should offer a number of opportunities for

the student to provide evidence of proficiency in the selected SEP, DCI, and CCC. The selected SEP, DCI, and CCC must be clearly stated from the beginning for both the teacher and the student. This statement of expectations can take the form of learning progressions. Directly teaching to the CCC as the unit progresses can lead to mastery in the SEP and DCI selected for that unit.

METHODOLOGY

The subjects of the study were the students in a ninth grade Earth science course at U-32 public middle and high school in East Montpelier, VT ($N=52$). While this is set up as a course for ninth-graders, five eighth graders opted to take this course in addition to their middle school science class, as well as, one 10th grader. The students were divided across three sections; all sections were composed of students with a range of science abilities. The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix A) and compliance for working with human subjects was maintained.

Student mastery of the cross-cutting concepts (CCC) and their confidence with the CCC was assessed alongside student mastery of the delivered science content. The treatment was conducted over one unit and in all three of the Earth science sections. Individual, partner, and group activities were used to introduce the CCC to the students. The first time the students were explicitly taught about the CCC was during the treatment. Prior to the treatment, the students were told the purpose of CCC and given the Crosscutting Concept List (Appendix B) of the seven CCCs that included each concept's definition. Examples of each CCC were not provided prior to the treatment period.

A CCC proficiency scale was created to test the effectiveness of proficiency scale (Table 1). The students were first introduced to the proficiency scale during the treatment period. The scale has two purposes; the first purpose being to act as a map of what their learning will look like, and the second purpose being to act as an explanation of the expectations for what the students need to know and understand to be proficient with the CCC. The CCC proficiency scale was periodically referenced to provide guidance for the students' learning and intention to our explicit instruction on the CCC. The teacher used the CCC proficiency scale to develop activities and assessments for the treatment period.

Table 1
Crosscutting Concept Proficiency Scale

CROSSCUTTING CONCEPTS	Beginning	Developing	Proficient	Advanced
Identify CCC in science	I can define the CCC.	Beginning + I can explain why the CCC the teacher gives me applies to a given scenario.	Developing + I can • Identify which CCC match the scenario. • I can explain why they match the scenario.	Proficient + I can compare examples in different domains of science (Earth science, biology, chemistry, physics) for the same CCC.

The students' mastery of CCC was assessed four times. Once before the treatment, once at the end of the treatment unit, and twice during the treatment. The CCC pre and post mastery tests were of similar format to each other but engaged students with different material. Students were given a description of a phenomenon to read. The students were then asked to reflect on the cross-cutting concepts involved in the phenomenon. The pretest was taken from a collection developed by the Curriculum Research & Development Group (CRDG), College of Education (2018). The content of

the pretest was related to sea level rise as a consequence of our current climate change (Appendix C). The test came at the end of the climate change unit. The background information on the posttest was taken from NASA's webpage (Dejoie & Truelove, n.d.) on cepheids. The posttest was related to astronomy and came at the end of the astronomy unit (Appendix D).

Two formative assessments were used to assess the students' skill at the beginning (Appendix E) and developing levels (Appendix F) corresponding to the CCC proficiency scale. The formative used to assess the *beginning* level asked the students to match a CCC with its definition. The formative used to assess the *developing* level was a graphic organizer (Workosky, 2017) the students used to apply a given CCC to a topic recently reviewed.

A CCC prescore based on the results of the CCC pretest was used to establish students' skill level prior to treatment. A CCC post score was used to determine skill level post treatment. The post score was based on the CCC posttest that was given at the conclusion of the treatment unit. The possible scores for the test were a zero to three. A zero signifies there is no evidence to assess the students' skill. Students were not directed to try for advanced on either the pre or post CCC test. However, if the student did not successfully identify and explain a CCC in the given scenario, scores from the two previous formative assessments were used to more accurately represent their ability to apply the CCC.

Descriptive statistics and the Sign Test were used to determine the significance of the pre and post CCC scores. The sign test was chosen due to the non-parametric and categorical nature of these scores due to the proficiency-based grading.

At the end of each unit, the students submitted an assessment to demonstrate their proficiency in the performance indicators. The assessment for the non-treatment unit required students to write a report on the effects of climate change (Appendix G). The assessment for the treatment unit required students to provide evidence for a claim related to the creation of our universe (Appendix H). Table 2 identifies the performance indicators scored in each unit.

Table 2
Proficiency Indicators Scored in Each Unit

Unit	DCI Indicator	SEP Indicator	Treatment
Climate Change	Use quantitative and qualitative data to create an evidence-based explanation for the causes and effects of climate change on earth systems.	Analyze grade level data to draw conclusions, and support them with specific evidence.	Non Treatment
Astronomy	Use qualitative and quantitative evidence to construct an explanation for the evolution of the universe.	Demonstrate use of research methods to answer questions. (constructing explanations).	Treatment

Descriptive statistics were used to determine if students' proficiency with the DCI increased during and after the treatment period. A score of proficient or advanced means the student demonstrated evidence of proficiency in the DCI. Quizzes and other forms of check-ins provided the students with feedback on their level of proficiency with the DCI.

Descriptive statistics were used to analyze the scores of the unit summative assessments to assess student understanding of the DCI. The Chi-squared test was used to determine association between teaching the CCC and students' mastery of the DCI.

Student confidence with the CCC was assessed using a confidence survey (Appendix I) that was administered at the beginning and end of the study. The survey used Likert style questions to ask about students' ability to complete tasks that were linked to the CCC. The definition for each CCC was given to the students on the survey. The language matched the definitions provided on the Crosscutting Concept List (Appendix B). This language was taken from the Matrix of Crosscutting Concepts in NGSS and was used to provide more detail on the CCC for the student as they took the survey (NGSS@NSTA). The survey asked students to rank their confidence in providing examples for each indicator. The Likert questions were coded to numerical equivalents in order to analyze descriptive statistics on the pre and post survey results.

Interview questions (Appendix J) were used to elaborate on students' confidence and mastery of the CCC. One student on a 504 plan or IEP from each of the sections were selected. Two students who previously demonstrated strength in science were selected from two of the sections. The responses from the five students provided qualitative data to support the data analysis from the before mentioned statistical tests. Eight questions were asked as a follow up to the students CCC mastery tests. The responses were coded to identify patterns in the data. A summary of all quantitative and qualitative data collection, as well as triangulation of data to support each research question is shown in Table 3.

Table 3
Data Triangulation Matrix

Research Questions	Data Source		
	1	2	3
Does explicit instruction around cross-cutting concepts paired with proficiency grading have impact on student mastery of the CCC & DCI?	CCC Pre/Posttests	Unit Assessments	Student Interviews
Does explicit instruction around cross-cutting concepts paired with proficiency grading have impact on student confidence?	CCC Survey	Student Interviews	Teacher Journal
Does the use of proficiency scales help with student mastery of the CCC?	CCC Pre/Posttests	Unit Assessments	Student Interviews

DATA AND ANALYSIS

The subjects of the study were fifty-two students in the ninth grade Earth science course. Forty-five of the fifty-two students' CCC scores were used for final analysis ($N=45$). Data for seven students were removed for more accurate results due to either pre or posttests not being completed. The scores were coded prior to analysis: no evidence of skill (0), beginning (1), developing (2), and proficient (3). The frequency of scores can be seen in Figure 2. The range of pre scores was limited to a score of 0 or a score of 3. The range of post scores fell into four categories from 0 to 3.

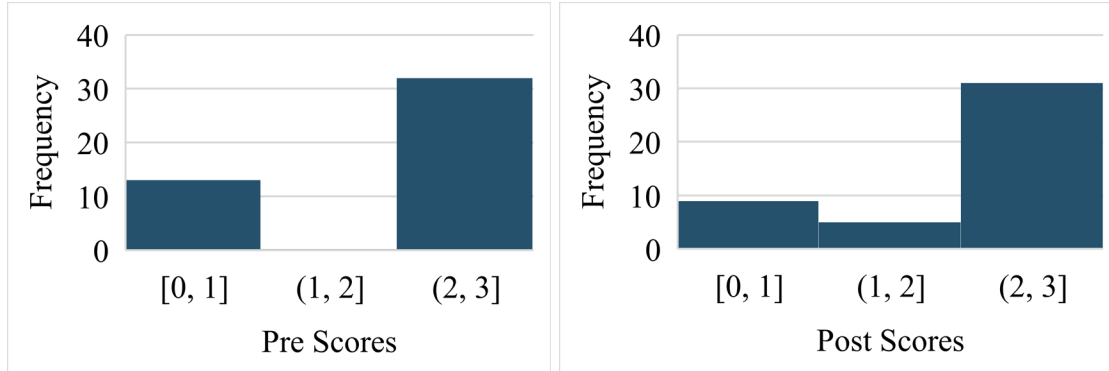


Figure 2. Histogram of pre and post scores, ($N=45$).

The difference between the pre and post scores was used to identify student ability in applying the CCC over the treatment period. The normalized gain was not used due to the large number of students who successfully scored a level 3 on both the pre and posttests. The majority of students did not demonstrate a change in their ability to apply the CCC over the course of the treatment (Figure 3). Fifty-six percent of the students' demonstrated a level 3 in both their pre and post scores. Eleven percent of the students showed no evidence of being able to work with the CCC and have a score of 0 for both their pre and post. Eighteen percent of the post scores were higher than the corresponding pre scores. Sixteen percent of the post scores were lower than the corresponding pre scores. The median pre score was a level 3. There was no change in the median score after the treatment period. The mean score between pre and post treatment also showed little change. The mean pre score was 2.13 with a standard deviation of 1.38 while the mean post score was a little higher at 2.33 with a tighter standard deviation of 1.13.

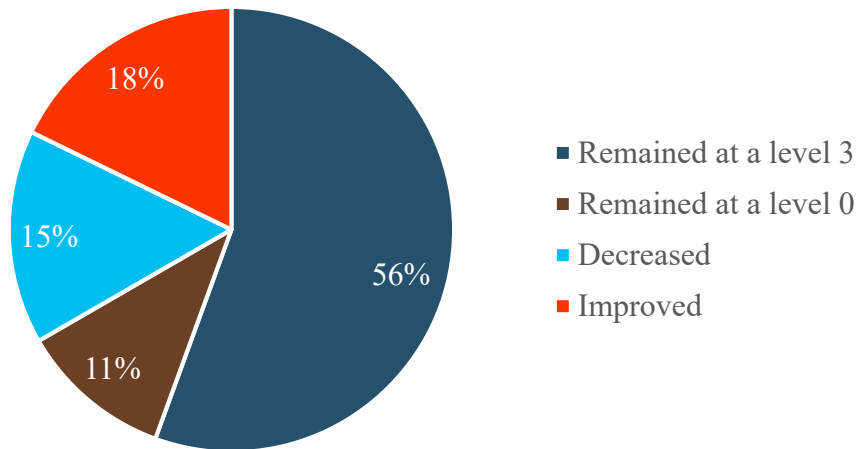


Figure 3. Difference in pre and post scores (post Scores – pre Scores), ($N=45$).

A Sign Test was used to compare the pre and post scores to determine the success of explicitly teaching the crosscutting concept. The sample size for the test was 15 due to dropping scores that showed no difference from the pre to the post scores ($N=15$). A Z-test statistic of 0.26 confirms that there is no statistical difference between the pre and post scores.

Forty of the fifty-two students' unit summative scores were used for final analysis ($N=40$). Twelve students did not take either the non-treatment or the treatment unit test. These scores were removed for more accurate results. The scores for the unit summative assessments were coded for analysis: no evidence of skill (0), beginning (1), developing (2), proficient (3), and advanced (4). Descriptive statistics were used to observe student understanding of the DCI taught during the non-treatment and treatment unit. The frequency of the unit summative DCI scores are shown in Figure 4.

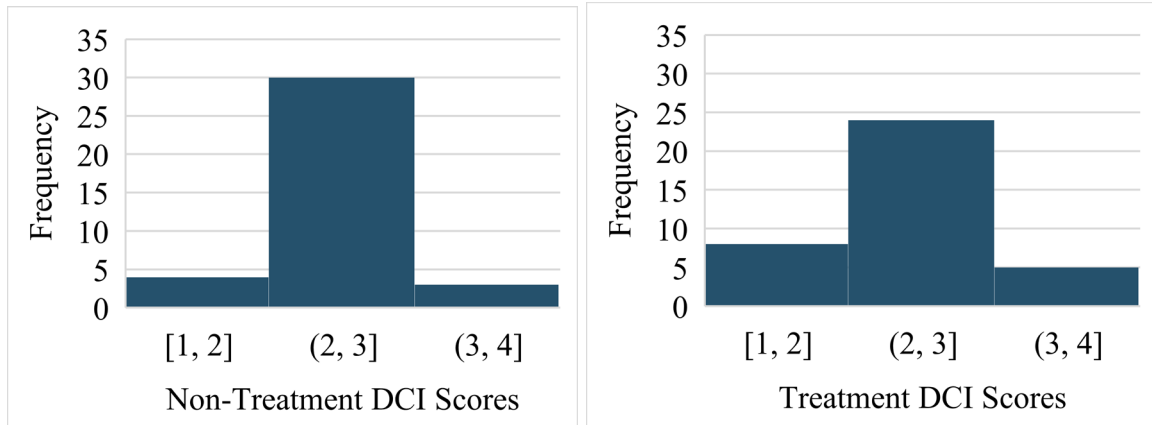


Figure 4. Histogram of non-treatment and treatment DCI scores, ($N=45$).

The median and mean for the non-treatment unit summative and the treatment unit's summative showed no change. The mean for both summative assessments was 2.88. The median was a level 3 for both the treatment and non-treatment scores. The standard deviation was lower for the treatment unit summative with a standard deviation of 0.69 compared to 0.72 for the non-treatment.

A chi-square test of association was used to determine a relationship between teaching of the CCC and students' understanding of the DCI. Scores from the CCC scores and the unit summative DCI scores were used for the chi-square test ($N=37$). The chi-squared value was 10.24 with a p-value of 0.04. The chi-squared value was large enough to reject the null hypothesis that the CCC and DCI are independent of each other. The chi-square test suggests that there is an association between direct teaching of the CCC and student understanding of the DCI.

Forty of the fifty-two students taking Earth science took the CCC Confidence Pre-Survey ($N=40$). This survey was administered prior to the treatment unit. The responses from the survey were coded for statistical analysis: strongly agree (1), agree (2), neutral (3), disagree (4), strongly disagree (5). Descriptive statistics on the Likert scale survey

questions suggest that the students' confidence with the crosscutting concepts was mostly neutral prior to the treatment unit. Only one student interviewed in the pretreatment interview felt confident about the CCC test they took. Figure 5 shows the median response to students ranking their confidence in their ability to give an example related to each of the seven crosscutting concepts. The questions on the survey are listed in Appendix I.

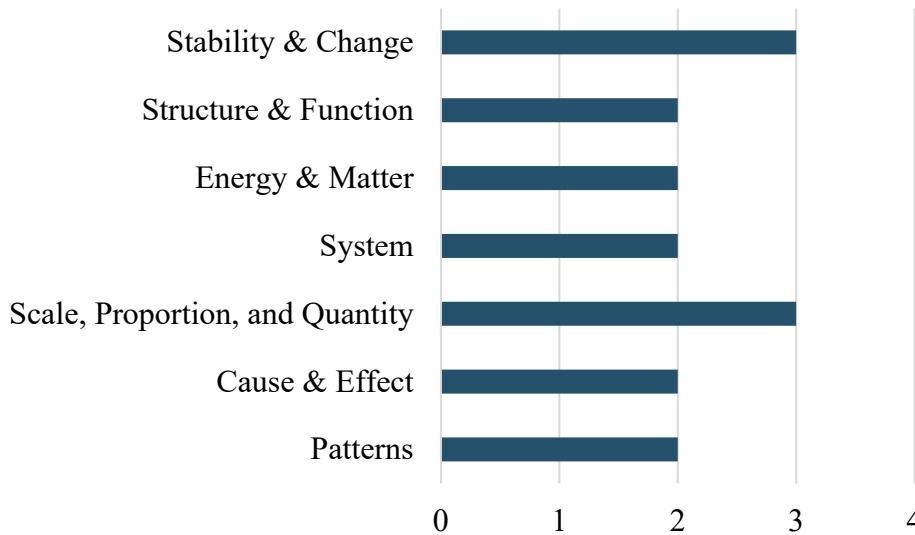


Figure 5. Median response in CCC confidence pre-survey, (N=40).

Students were most confident with their ability to give an example of a cause and effect relationship. The median score for this crosscutting concept was a 2; indicating that, on average, students agreed they felt confident in their ability to give an example(s) of cause and effect. Students felt the least confident with their ability to give an example related to the energy and matter crosscutting concept. Fourteen students either disagreed or strongly disagreed with the statement, “I feel confident in my ability to give an example(s) of Energy & Matter.” Figure 6 shows the confidence responses for each of the seven crosscutting concepts.

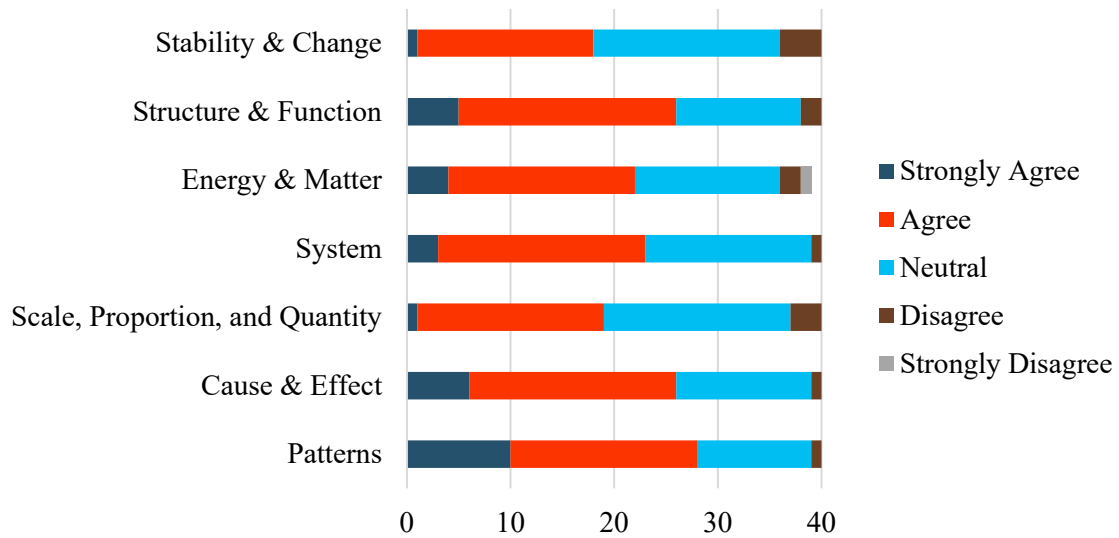


Figure 6. Confidence responses in the CCC confidence pre-survey, ($N=40$).

Forty of the fifty-two students taking Earth science took the CCC Confidence Post Survey ($N=40$). This survey was administered at the completion of the treatment unit. The responses from the survey were coded for statistical analysis: strongly agree (1), agree (2), neutral (3), disagree (4), strongly disagree (5). Descriptive statistics on the Likert scale survey questions suggest that the students mostly agree with the statement that they are able to give examples of the crosscutting concepts. Two students said they felt confident about the CCC posttest they took. Three students still felt unsure about their ability to complete the CCC posttest. Figure 7 shows the median response to students ranking their confidence in their ability to give an example related to each of the seven crosscutting concepts. The questions on the survey are listed in Appendix I.

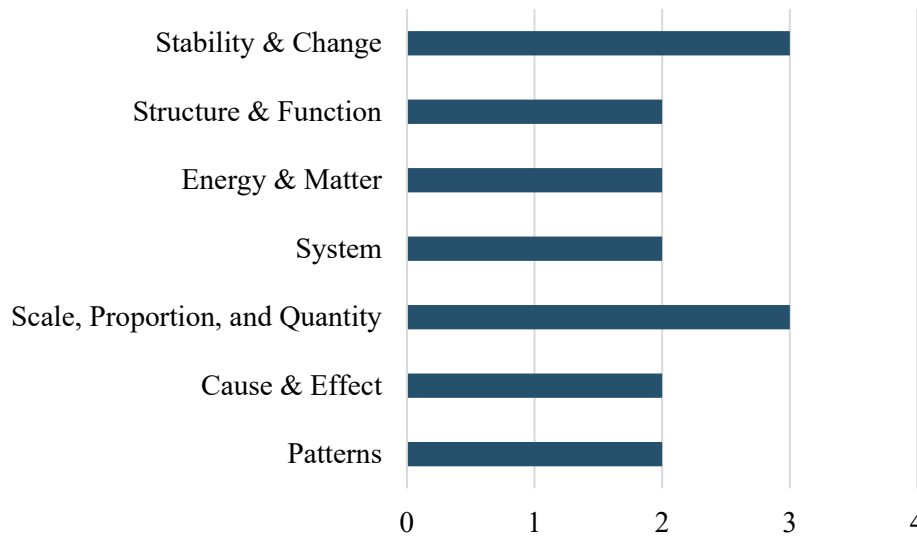


Figure 7. Median response in CCC confidence post survey, (N=40).

Twenty-eight students either agreed or strongly agreed with the statement that they could give an example of patterns indicating that students were the most confident this crosscutting concept. Twenty-six students either agreed or strongly agreed with the statement that they could give an example of structure and function indicating that students were also confident with this crosscutting concept. Students felt the least confident with their ability to give an example related to the crosscutting concept scale, proportion, and quantity, as well as, stability and change. The median response was neutral for both the crosscutting concept scale, proportion, and quantity, as well as, stability and change. Figure 8 shows the confidence responses for each of the seven crosscutting concepts.

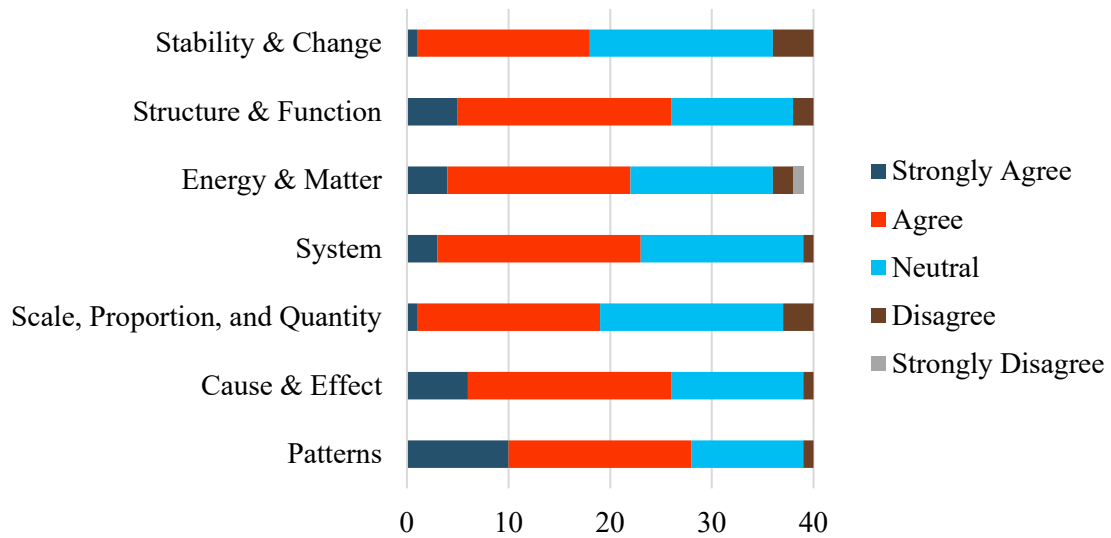


Figure 8. Confidence responses in the CCC confidence post survey, ($N=40$).

INTERPRETATION & CONCLUSIONS

This project set out to answer whether explicit instruction around cross-cutting concepts paired with proficiency grading had an impact on student mastery of the CCC & DCI. The sign test suggested that there was no significant difference between the CCC pre and post scores. A Z-test statistic of 0.26 was too small to reject the null hypothesis that that there was no difference between the pre and post scores. The sample size for this test was very small ($N=15$) due to the large number of scores that were dropped because there was no difference between the pre and post scores. The sample size was also affected by only using data with paired responses.

Changes to administration and content should be made to future CCC posttests. Interviews with students revealed telling feedback. The non-treatment CCC pretest included content that students had not explicitly learned about in their Earth science lessons but were exposed to in their global studies course. The content was also more intuitive and perhaps a lower reading level. The treatment CCC posttest elaborated on

content learned in class but was a more challenging read that discussed less intuitive astronomical measurements. One student explained that the posttest was more challenging because the class “never spoke of the content”. Another student said they were “confused on what [they] read”.

The summative for the treatment unit and the CCC posttest were administered during the same class period. Interviews with students afterwards revealed that the amount of testing led to disengagement during the CCC test. If this were to be completed in the future, testing should be administered in separate sittings to encourage more robust responses.

Descriptive statistics showed no change between the unit summative assessments that assessed students’ understanding of DCI. The mean and the median were the same for the non-treatment summative and the treatment summative. The median score was a level 3 which is the needed score to demonstrate proficiency in the DCI. What this study did not take into account was that students were able to re-perform on the unit summative assessments until they reached a level 3. Identifying whether or not the number of times a student needs to reperform is associated with explicit teaching of the CCC could be an extension to this study.

The chi-squared test for association was used to determine the independence between teaching the CCC and student understanding of the DCI. Similar to the sign test, only data with paired responses were used for the chi-squared test which affected the sample size. The chi-square test suggested that there was an association between direct teaching of the CCC and student understanding of the DCI. The chi-squared test cannot

be used to determine how large that association is or in what direction the association is.

It cannot be said if the CCC are positively or negatively impacting the DCI.

In addition to investigating the impact of explicit teaching of the CCC on mastery, the study explored the impact of practicing the CCC on student confidence. Students confidence with the CCC improved over the treatment period. The median response on each of the seven CCC improved from *neutral* to confident after the treatment period. The median response was *neutral* to being able to provide examples of six of the seven CCC prior to treatment. The median response was that they *agree* to being able to provide examples of five of the seven CCC after treatment. Prior to the treatment, the students did not have any exposure to being asked to apply a CCC to a particular topic. During the treatment students watched me apply CCC, worked with partners to apply CCC, and individually explained how a CCC could apply to a given topic. The treatment only exposed students to three different CCC: patterns, energy and matter, and structure and function. Patterns and structure and function had the highest confidence rankings on the post survey.

A sub question of this study was whether the use of proficiency scales help with student mastery of the CCC. The only comparison in the use of scales can be made with the pre and post CCC scores. The CCC scale was introduced and used during the treatment period. The unit summative assessments used proficiency scales as all teaching at U-32 middle and high schools is proficiency-based, therefore, a comparison between the non-treatment unit summative and the treatment unit summative cannot be made. As discussed earlier, the results of the sign test implied that there was no difference between

the CCC pre and post scores. Those results suggest that the conclusion cannot be made that the use of a proficiency scale contributes to student mastery.

VALUE

From this experience, I have gained an enhanced understanding of 3D learning that is promoted by NGSS. More specifically, I have a better understanding of the role CCC can play in increasing student understanding. An association was made between explicit teaching of the CCC and student's understanding of the DCI. The magnitude and direction cannot be statistically determined from this study. However, observations of students' work and interaction with the course material suggests that by applying the CCC to science content students interact with the material at a higher level. The action is automatically differentiated for the student's own perspective allowing for creative, higher level thinking. Students' confidence with the CCC also increased over the study.

The more the students practiced with the CCC the more confident they grew, as experience would dictate. In the treatment unit, we did not engage all seven of the CCC and yet the majority of students' confidence increased with more of the CCC than from before the treatment. The six-week treatment was the first time the students were asked to think about making connections to themes in science. From the interviews with students, two of the five students found that they were able to make connections to the CCC on their own. From this statement, one might conclude that our students need more exposure to making connections to bigger themes rather than thinking of topics in a box: science versus global studies, biology versus chemistry. In ninth grade, students take Earth science and promptly move on to biology in tenth grade. Often students are not asked to

use information learned from Earth science in biology. NGSS is asking students to begin making connections across disciplines in an educational environment that has established (or boxed) disciplines.

More specifically speaking, this project offered me the opportunity of explicitly incorporating the CCC into my curriculum. After this experience, I will seek out and prioritize activities that ask students to engage with the content through the lens of a CCC. NGSS promotes 3D learning with curriculum intertwining DCI, SEP, and CCC. Asking students to identify CCC to the science topics learned in class, offered a new venue for interaction with the DCI. Despite the results showing no improvement in application of CCC over the course of the treatment, the successful application of CCC required students to have a deeper level of understanding of the topic.

Asking students to explain how ‘energy and matter’ relate to a particular topic, requires them to engage with the material in an unprescribed way. This task proved challenging for some high fliers who were used to following a script to navigate through school. There were many correct responses to how a CCC might be applied to a particular topic. However, coming to the answer requires the students to reflect on the topic with the particular direction of a CCC. This type of reflection proved challenging for some students, including students who were used to excelling in the classroom.

While some students were stumped by the open-endedness of the prompt, “explain how a CCC applies to this topic”, I observed other students succeeding. The task of connecting science content to CCC gives students a non-intimidating way of interacting with the material. In a way, this removes the pressure a student might feel

when they are trying to think of the answer the teacher wants them to say. It allows students a chance to be creative and think about a topic from their own perspective. I observed that some peer-to-peer teaching roles were more often flipped when working on our CCC activities. The students whose work I used as exemplars or the students I asked to help their classmates were often those who were new to this type of role. This changed the dynamic of the classroom in these instances.

Prior to this project, I was unclear as to the best method for incorporating the CCC into a curriculum. The use of the graphic organizer assisted in supporting student interaction with the CCC. The graphic organizers (Appendix F) provided the guidance the students needed in order to know how to interact with the content. The graphic organizers were generic enough that they allowed for the creative thinking of the student. They also gave me the framework for how to introduce a particular CCC to the students.

The use of the proficiency scale also contributed greatly to the building of the CCC curriculum. The scale provided guidance on how to introduce the CCC to the students, as well as, direction on assessing their skills with the CCC. The CCC tests failed to directly give students the opportunity to try for *advanced*. If students wanted to go beyond *proficient*, they would have needed to have looked at the scale and pursued on their own. The students at U-32 middle and high school are not at this level of taking responsibilities for their learning. In the future, more guidance on pursuing an *advanced* score is needed. Fifty-six percent of students scored a three on the pretest and the posttest. These students could have been pursuing an *advanced* score.

My experience with proficiency-based learning so far has been cyclical: create, revise, implement. The introduction of the CCC proficiency scale holds true to that experience. Now that I've used the scale from start to finish, I'd like to adjust it. Literature supports the challenge of scales acting as road map for the progression of learning for students. However, the construction of scales should take into account that there is not one progression for a classroom of unique students. The scale should be adjusted for use beyond just an introduction to CCC, but rather to support continuous use of the CCC. The scale used for this project lends itself to scaffolding activities perhaps more than a progression of learning. For example, being able to explain how a topic applies to a given CCC is a scaffolded activity and does not necessarily reflect the level of understanding the student has. Some unanswered questions on the best structure of the scale still remain. Such as, should there be one scale or multiple scales for each CCC?

In some ways, it was challenging to assess students' ability to apply CCC in a proficiency-based system. The students who had a strong understanding of proficiency-based learning had a harder time settling into that rhythm. Some often asked me what performance indicator would be used to score the pretest, posttest, or activity we were currently working on. The reality was that their scores would not be affected since the CCC performance indicator was not one chosen by U-32 as a graduation requirement. Some of these students voiced their frustration with needing to work on CCC while other students seemed satisfied with the explanation that CCC would help them gain a deeper understanding of the content and make connections to other areas of science. Early on in the study, I was worried that implementing an additional performance indicator that had

no impact on course score would disrupt the flow of the classroom. However, the majority of the students settled into the rhythm of working with CCC with ease.

As I moved through the project, I found myself reflecting more formally on potential future action research questions. As the project drew to a close, I reflected on how the project might be improved if ever completed again. Some possible changes may be using refined interview questions or additional instruments, as well as, adjustments to the CCC proficiency scale. The results of the project leave me wondering what relationship exists between the CCC and DCI and to what magnitude.

While literature and personal classroom observation supports a positive relationship between the CCC and DCI, this project failed to statistically support that claim. A future project that results in statistical significance would offer a better understanding of the relationship. The results of this future project would allow me to determine how much classroom time a student should spend making connections between CCC and DCI. The data would also be helpful in supporting future decisions our science department makes regarding proficiency especially due to the close connection some of our standards have with the CCC. The results of a future project might help answer if a student's proficiency is dependent on making connections across science disciplines, or if a student needs to touch on each CCC in each of their science classes. The results of this study would be relevant to our current future planning of what a U-32 science graduate would need to know, understand, and do.

Generally speaking, this project offered me the opportunity to pursue a question I hoped might improve my teaching. Future classes and curriculum will be affected by the

results of this project. Most significantly, students will be asked to make connections between the content and CCC for a more deliberate 3D curriculum.

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APPENDICES

APPENDIX A
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

2155 Analysis Drive
 c/o Microbiology & Immunology
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-4707
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-4706
 cherylj@montana.edu

MEMORANDUM

TO: Christine Fitch and Kathryn Solberg

FROM: Mark Quinn, Chair *Mark Quinn cy*

DATE: December 3, 2018

RE: "Assessing Gaps in Service and Expectations" [CF120318-EX]

The above research, described in your submission of November 30, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B
CROSSCUTTING CONCEPT LIST

LIST OF THE 7 CROSSCUTTING CONCEPTS

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Cause & Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

System & System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Energy & Matter

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Structure & Function

The way an object is shaped or structured determines many of its properties and functions.

Stability & Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

APPENDIX C
CCC PRETEST

CROSSCUTTING CONCEPT PRE TEST CLIMATE CHANGE

Background Info

Over half of all Americans live within 50 miles of the coastline. Most major cities are found near bodies of water. Small island nations—particularly in the central and south Pacific Ocean basins—are under threat of flooding as a result of rising sea levels.

Rising sea levels can negatively affect people living in coastal regions through increased coastal erosion. Shorefront homes and businesses are particularly vulnerable to coastal flooding or wave damage (SF Fig. 3.6 A).

Figure 3.6 A. A satellite photo of Waikiki, Hawai'i, has been modified to show potential flooding due to sea level rise. Red indicates saltwater intrusion predicted by 2050.



Low-elevation coastal communities also face greater risk from storms as a result of rising sea levels (SF Fig. 3.6 B).

Figure 3.6 B. Coastal Storm Surge Damaged Casino Pier during Hurricane Sandy in Seaside Heights, New Jersey.

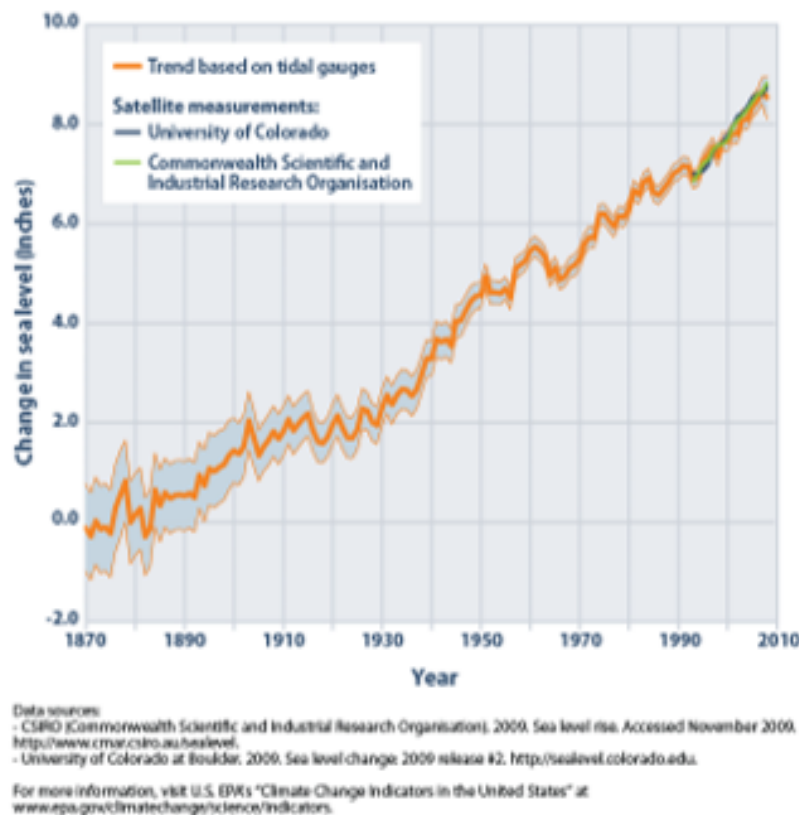


Sea levels are rising due to global climate change. This is occurring through two mechanisms: thermal expansion of water and melting ice formations on land. As world ocean temperatures rise with climate change, seawater expands to a slightly larger volume. Warm water has a slightly larger volume than cold water. Global climate change has also caused increased melting of major ice formations on land.

Melting land ice flows into the ocean and increases the sea level. However, not all melting ice increases sea level. It is a misconception that melting icebergs and sea ice causes the sea level to rise. A melting iceberg is similar to an ice cube melting in a glass of water. The volume of the water in the glass does not change when the ice cube melts. Melting sea ice does not contribute to rising sea levels. However, the increased rate of sea ice melting is an indication of global climate change.

The earth's sea levels remained relatively consistent from the first century AD until 1900. Since then, scientists have observed sea levels rising by one to two-and-a-half millimeters per year. The most recent data collected by satellite instruments estimates a rate of three millimeters increase in sea level per year. This rate of sea level rise is expected to increase in the future as global climate change progresses (SF Fig. 3.7).

Figure 3.7. Trends in Global Average Absolute Sea Level, 1870-2008



Source: Curriculum Research & Development Group (CRDG), College of Education. (2018). Climate Connections: Sea Level Rise. Retrieved from <https://manoa.hawaii.edu/exploringourfluidearth/physical/atmospheric-effects/effect-surface-currents/climate-connections-sea-level-rise>

Name: _____ Section: W6 W7 W8 Date: _____

Describe and explain the crosscutting concepts involved in this global sea level rise scenario.

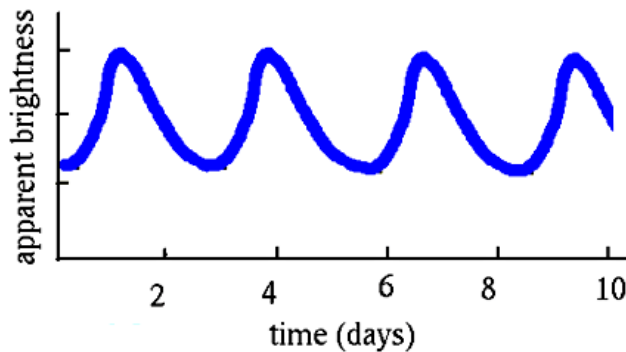
Note: You may use the list of crosscutting concepts handout

APPENDIX D
CCC POSTTEST

CROSSCUTTING CONCEPT POSTTEST

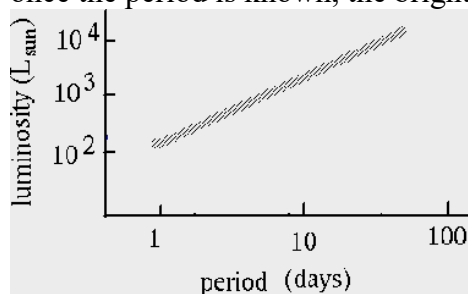
ASTRONOMY

We recently read about how the astronomer Adam Riess recalculated the Hubble Constant. The implication of the new calculation is that the universe is expanding faster and, therefore, may be younger than originally understood. But what did he base this new calculation on? He used the pulse rate from 70 cepheid stars. To better understand how this would help him, read the explanation from NASA on cepheid stars.



Cepheids, also called Cepheid Variables, are stars which brighten and dim periodically. This behavior allows them to be used as cosmic yardsticks out to distances of a few tens of millions of light-years.

In 1912, Henrietta Swan Leavitt noted that 25 stars, called Cepheid stars, in the Magellanic cloud would brighten and dim periodically. Leavitt was able to measure the period of each star by measuring the timing of its ups and downs in brightness. What she determined was that the brighter the Cepheid, the longer its period. In fact, Cepheids are very special variable stars because their period (the time they take to brighten, dim and brighten again) is regular (that is, does not change with time), and a uniform function of their brightness. That is, there is relation between the period and brightness such that once the period is known, the brightness can be inferred.



Cepheids are reasonably abundant and very bright. Astronomers can identify them not only in our Galaxy, but in other nearby galaxies as well. If one requires the distance to a given galaxy one first locates the Cepheid variables in this galaxy. From these

observations one determines the period of each of these stars. Leavitt's data states that a given period has a unique brightness associated to it. So from the period and Leavitt's plot we get the brightness at the distance of one light-year (see the image above). We can also measure the brightness on Earth. The brightness at the distance of one light-year will be larger than the observed brightness due to the fact that brightness drops like the square of the distance. From these numbers one can extract the distance to the stars. This method works up to 13 million light-years when Earth-bound telescopes are used; for larger distances these stars become too dim to be observed. Recently, space-based telescopes such as the Hubble Telescope, have used these stars to much farther distances. Looking at a galaxy in the Virgo cluster called M100, astronomers used the Cepheid variables observed there to determine its distance - 56 million light-years.

Describe and explain a crosscutting concept involved in cepheid variables scenario.

Note: You may use the list of crosscutting concepts handout

APPENDIX E

FORMATIVE ASSESSMENT, BEGINNING LEVEL

CROSSCUTTING CONCEPTS	1	2	3	4
Identify crosscutting concepts (CCC) in science	I can define the CCC.	Beginning + I can explain why the CCC the teacher gives me applies to a given scenario.	Developing + I can ... - Identify which CCC match the scenario. - I can explain why they match the scenario.	Proficient + I can compare examples in different domains of science (Earth science, biology, chemistry, physics) for the same CCC.

Match the crosscutting concept with their correct definitions.

PATTERNS	--Events have causes. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
ENERGY & MATTER	--For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
CAUSE & EFFECT	--Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena
STRUCTURE & FUNCTION	--Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.
STABILITY & CHANGE	--It is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
SYSTEM & SYSTEM MODELS	--The way an object is shaped or structured determines many of its properties and functions.
SCALE, PROPORTION & QUANTITY	--A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

APPENDIX F

FORMATIVE ASSESSMENT, DEVELOPING LEVEL

Applying **Structure & Function** to the Phenomenon of Star's Life Cycle

1) Describe the phenomenon.

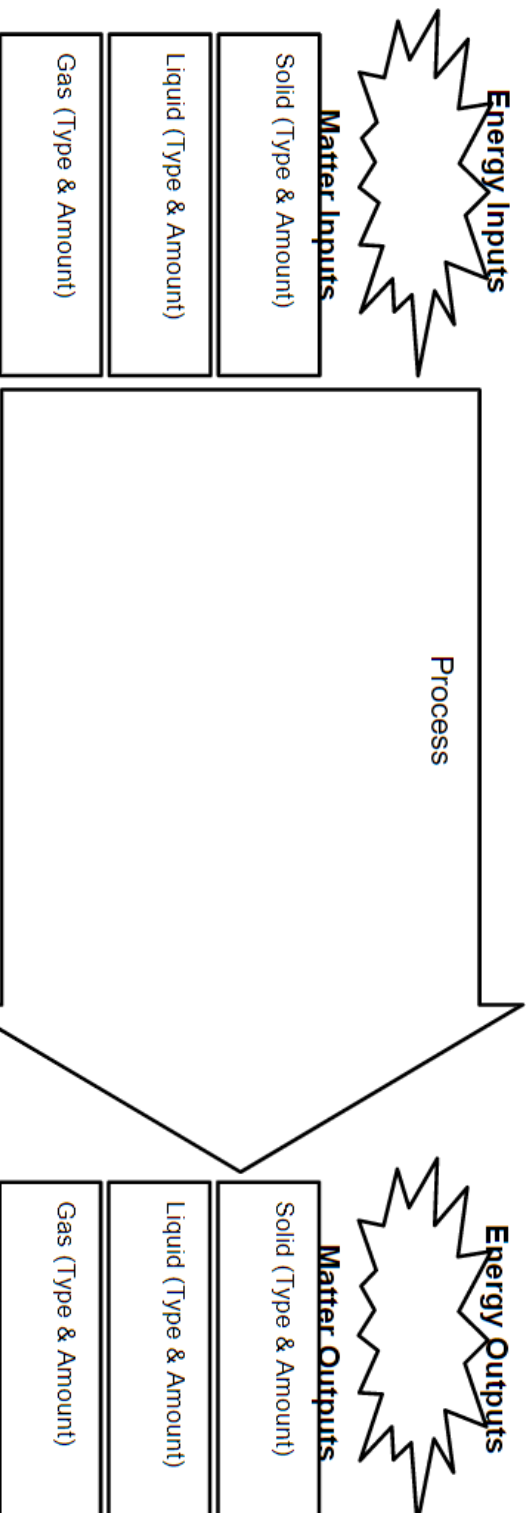
2) Draw and label the structure, including any important subcomponents or material properties.

3) Explain how the function of the system depends on the structure and properties of the components.



4) How will this structure- function relationship help you explain the phenomenon?

Applying Matter & Energy to the Phenomenon of Nuclear Fusion



- 1) Describe the process and complete the inputs and outputs above.
- 2) Does your evidence show that ~~matter~~ energy and energy were conserved? If not, how can you account for this?
- 3) How is the movement of matter connected to the flow of energy in this process?
- 4) How are energy and matter transformed during this process?

Adapted from: http://www.pathwaysproject.kps.msu.edu/?page_id=51

APPENDIX G

CLIMATE CHANGE (NON-TREATMENT) UNIT ASSESSMENT

CLIMATE CHANGE SUMMATIVE

Vermont's Climate Change Report

A report on the causes and effects of climate change is requested by State legislators. Your report should focus on one Earth system of your choice. Your claims must be supported by both *quantitative* and *qualitative* data. The expectation is that each student will submit their own work for this report. The following rubric will be used to assess your report:

SC4: SUSTAINABILITY- Understand that humans' impacts are greater than they have ever been, as are humans' abilities to model, predict, and manage current and future impacts in order to maintain human societies and the biodiversity that sustains them.				
PI SC4a	1	2	3	4
Climate Change: Use quantitative and qualitative data to create an evidence-based explanation for the causes and effects of climate change on earth systems	I can identify sources that could cause (human or natural) climate change on Earth systems.	Beginning + When given the human activity or natural cause, I can identify the relevant effect of climate change on Earth system.	Developing + I can use relevant data as evidence when formulating an explanation about the causes (human or natural) and effects of climate change.	Proficient + Using extrapolation, I can hypothesize what the future change on Earth systems will be (including sources, causes, and effects).

SC6: DESIGN, CONDUCT & ANALYZE SCIENCE INVESTIGATIONS: Design investigations that generate data to provide evidence that supports claims they make about phenomena.				
PI SC6f	1	2	3	4
Analyze data to draw conclusions and support them with specific evidence.	I can use technology to display data I have collected.	I can correctly analyze data using technology to draw conclusions.	I can analyze data using tools, technologies, mathematical concepts and/or comparisons to models to recognize patterns and draw conclusions and support them with specific evidence.	Based on data analysis that I have conducted, I can consider ways that my data would change if I modified my procedure.
Looks Like ...	I can visually display data with a table and graph.	I can make accurate claims from the data.	I can support my claims with specific evidence from the data.	I can extrapolate the data to predict future changes to that variable.
Example		Looking at the trend in worldwide ocean temperatures over the last 100 years I can see there is an upward trend in temperatures	Average temperatures of the world's oceans increased from 12.21°C in the early part of the 19th century and to 12.37°C in 1922.	I anticipate the average temperature of the world's ocean to continue to increase at a rate of 0.08°C per decade. At this rate, ocean temperatures will be around 16.5°C in 2050.

Checklist for Tables:

- Title
- Variable headers with units
- Data in appropriate columns

Checklist for Graphs:

- Title
- Axes labels with units
- Appropriate graphic representation
- Data on appropriate axes
- Trendline if necessary

Use the following outline and checklist to organize your report. Your Evidence Log for Causes & Effects of Climate Change should be your primary resource. However, you may need to do additional research to meet all of the report criteria.

Introduction

- ☐ Hook on why climate change and its effects matter to you and/or Vermont
- ☐ Claim 1
- ☐ Claim 2
- ☐ Identify the *Earth system* you will be discussing and how it works (*before being affected* by changing climate.)

Causes of Climate Change

- ☐ Claim about how a natural source affects climate
 - ☐ Evidence
- ☐ Claim about how anthropogenic sources affect climate
 - ☐ Evidence
 - ☐ Include evidence in the form of data/graphs etc. showing changes in climate before and after we started to contribute to the problem
 - ☐ Graphs/Tables must meet the criteria in the checklist found on the first page

Effect of Climate Change on Earth system

- ☐ Claim 1 about how an Earth system is being affected by climate change
 - ☐ Evidence 1
 - ☐ Evidence 2
- ☐ Claim 2 about how an Earth system is being affected by climate change
 - ☐ Evidence 1
 - ☐ Evidence 2
- ☐ Explanation of consequence(s) of the Earth system being affected
 - ☐ Impact on culture and community in Vermont

(optional) Climate change and analysis level 4

- ☐ Hypothesize what the future change on the Earth system will be.
- ☐ Identify what source of climate change will affect the system.
- ☐ Extrapolate your climate graphs to support your hypothesis.
- ☐ Reference climate scenarios/models to support your hypothesis.

Conclusion

- ☐ Restate your claims

Checklist:

- ☐ Title, Name, & Group #
- ☐ Works Cited

APPENDIX H

ASTRONOMY (TREATMENT) UNIT ASSESSMENT

Evolution of the Universe Summative Assessment

Write a well-reasoned argument for a chosen claim related to the evolution of our universe that is supported by evidence.

Performance Indicators

P.I. SC3d Evolution of the Universe	1	2	3	4
Use qualitative and quantitative evidence to construct an explanation for the evolution of the universe.	I restate facts related to the evolution of the universe.	Beginning + I compare information related to the evolution of the universe.	Developing + I effectively synthesize the information related to the evolution of the universe.	Proficient + Based on the information I have been presented, I propose the future evolution of the universe.

**Expected Score: 3*

TS5: INFORMED, INTEGRATED, AND CRITICAL THINKING - Use a variety of sources to understand, interpret, analyze, and evaluate information.				
P.I. TS5c	1	2	3	4
Demonstrate use of research methods to answer questions.	I can ask questions to clarify comprehension. Identify and summarize information from relevant sources to develop appropriate research questions. Use evidence and reasoning to justify claims, citing sources.	Beginning + I can ask a researchable question and collect reliable evidence to support a claim, citing sources.	Developing + I can develop a well-reasoned argument that includes counterclaims and cites sources.	Proficient + I can ask a researchable question and collect relevant, reliable evidence to support a precise and nuanced claim; fully addresses and responds to clearly stated questions and/or counterclaims in a way that sharpens the argument; content is accurate, conveys depth and breadth of knowledge on topic, and seamlessly supports the claim.

**Expected Score: 3*

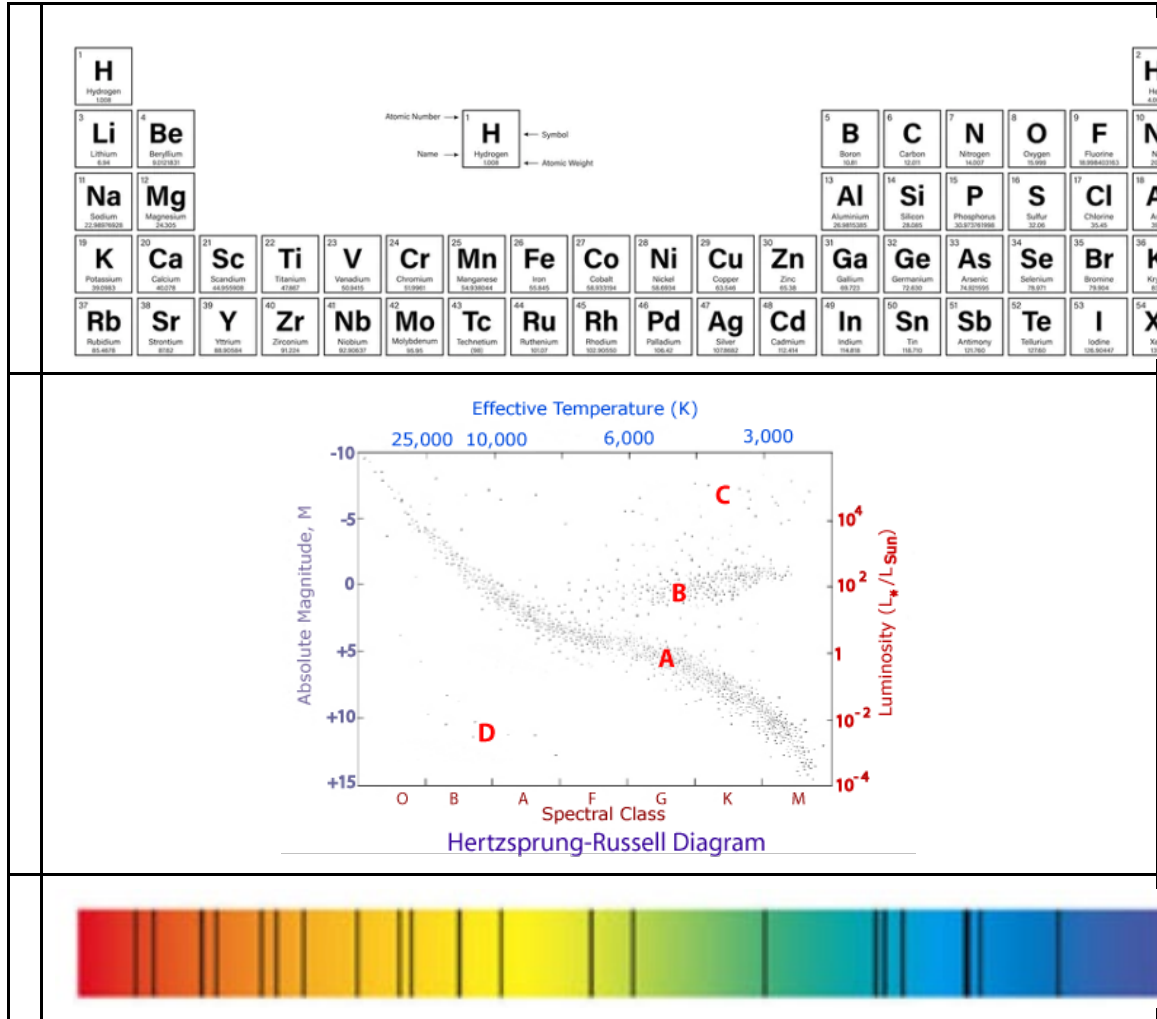
I. Choose one of the claims below; copy and paste your choice into step III A.

- A. The universe began as a point of singularity and has been expanding ever since.
- B. The beginning of the a star's life plays an important role in how it ends its life.

II. Choose the best pieces of evidence to support your claim chosen above. Be sure to find counterclaims (or “new findings”) as well. Copy and paste your chosen evidence to step III B & C. Copy and paste your counterclaim (or “new findings”) into step E.

	Born in Washington, D.C., on February 3, 1921, Ralph was the youngest of four children of building contractor Samuel and Rose Maleson Alpher, immigrants from Russia and Latvia.
	Finding no explanations for the origin of the noise, Penzias & Wilson finally concluded that it was indeed coming from space, but that it was the same from all directions. It was a distribution of microwave radiation which matched a blackbody curve for a radiator at about 2.7 Kelvins.
	Luminosity and surface temperature are two other indicators that we can use to better understand stars. Luminosity refers to the brightness of the star relative to the brightness of our sun. Surface temperature is measured through the color of the star.
	Alpher developed the ideas of “hot” big bang cosmology to a high degree of physical precision, and was the first to present the idea that radiation, not matter, predominated the early universal adiabatic expansion first suggested by A. Friedmann in the early 1920s.
	...they learned of the serendipitous detection of the cosmic microwave background by Arno Penzias and Robert Wilson in 1965 and found that their model temperature (with updated values of cosmological parameters) was in agreement with the 3K measurement.
	The universe is expanding faster than it used to, meaning it’s about a billion years younger than we thought, a new study by a Nobel Prize winner says...At issue is a number called the Hubble constant, a calculation for how fast the universe is expanding...Using NASA’s Hubble Space Telescope, Johns Hopkins University astronomer Adam Riess concluded in this week’s Astrophysical Journal that the figure is 9% higher than the previous calculation, which was based on studying leftovers from the Big Bang.
	Alpher & Herman predicted in 1948 and 1949 the temperature of the universe at around 5K.
	When the density and temperature are high enough, nuclear fusion occurs and Hydrogen is <u>converted into Helium</u> . Eventually, the outward pressure generated by the fusion reactions balances the gravitational force, the shrinkage stops, and the gas cloud becomes a star.

	Hubble's law, as it is known, indicates that galaxies are moving away from each other at speeds proportional to their distance. In other words, the farther something is away from us, the faster it is moving away.
	Beyond Iron the nuclear fusion process cannot release any more energy, and a red giant star reaches the end of its life.
	It was already known that nebulae appeared redder than they should be. Astronomers, notably Vesto Slipher, had found that the light from most nebulae was redshifted, indicating that most of the nebulae were receding at high speeds.
	All electromagnetic waves travel at the speed of light but vary in terms of their wavelength.
	The Doppler Effect is the phenomenon that wavelengths can expand and compress based on your relative speed compared to them.
	The star lies half a billion light years away in the constellation of the Great Bear. It has exploded multiple times since 1954...
	The curious incident came to light after astronomers detected a supernova in September 2014. They detected it with the Intermediate Palomar Transient Factory (iPTF) telescope near San Diego. The exploding star seemed unremarkable at first. But observations four months later showed that rather than dimming over time as expected, the supernova had actually become brighter.
	Emission spectra lines are the black lines that show up on the visible light spectrum; they tell us what elements are present in stars and galaxies.
	The diagram illustrates the electromagnetic spectrum with the following components: Penetrates Earth Atmosphere? A bar indicating penetration: Radio (Y), Microwave (Y), Infrared (N), Visible (Y), Ultraviolet (N), X-ray (N), Gamma Ray (N). Wavelength (meters): A scale from 10^3 (Radio) to 10^{-12} (Gamma Ray). Visible light is noted as $.5 \times 10^{-6}$ meters. About the size of...: A visual representation of wavelengths with corresponding icons: Buildings, Humans, Honey Bee, Pinpoint, Protozoans, Molecules, Atoms, and Atomic Nuclei. Frequency (Hz): A scale from 10^4 (Radio) to 10^{20} (Gamma Ray). Temperature of bodies emitting the wavelength (K): A scale from 1 K (Radio) to 10 Million K (Gamma Ray).



III. Write your well reasoned argument below.

A. What is the claim you are explaining? (P.I. SC3d, level 1)	
B. What is your first piece of evidence that supports your claim? (P.I. SC3d, level 2; TS5, level 2)	
C. What is your second piece of evidence that supports your claim? (P.I. SC3d, level 2; TS5, level 2)	
D. How do <u>both</u> pieces of evidence best support your claim? (P.I. SC3d, level 3; TS5, level 2)	
E. What is your counterclaim (or new findings) evidence? (TS5, level 3)	
<i>Optional Level 4 Work Below</i>	
F. Address the implication the counterclaim has on your claim? (TS5, level 4)	
G. What do you propose for the future evolution of the universe? (P.I. SC3d, level 4)	

APPENDIX I
CCC CONFIDENCE SURVEY

Confidence Survey on Cross-Cutting Concepts

Participation in this research is voluntary and participation or non-participation will not affect your, the student, score or class standing in any way.

* Required

Email address *

Your email

What Earth science section are you in? *

- ☐ W6
- ☐ W7
- ☐ W8

When reflecting on your confidence with the cross-cutting concepts below, your examples do not need to be from Earth science but rather any science subject area.

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

I feel confident in my ability to give an example(s) of Patterns

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Cause & Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

I feel confident in my ability to give an example(s) of Cause and Effect

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

I feel confident in my ability to give an example(s) of Scale, Proportion, and Quantity

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Systems & System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

I feel confident in my ability to give an example(s) of Systems & System Models

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Energy & Matter

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

I feel confident in my ability to give an example(s) of Energy & Matter

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Structure & Function

The way an object is shaped or structured determines many of its properties and functions.

I feel confident in my ability to give an example(s) of Structure & Function

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

Stability & Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

I feel confident in my ability to give an example(s) of Stability & Change

Strongly Agree	☐
Agree	☐
Neutral	☐
Disagree	☐
Strongly Disagree	☐

☐ Send me a copy of my responses.

SUBMIT

APPENDIX J
INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

Looking at your response to the CCC Test, how confident are you with it? Explain.

Pick a cross-cutting concept that you can connect to our unit?

Why do you choose this one?

Can you give me an example that applies to a cross-cutting concepts ? It doesn't have to be Earth science related.

Give the student the CCC List

Have you noticed some of our cross-cutting concepts outside of science?

While we were studying this past unit, did you ever find yourself making a connection to one of the crosscutting concepts?

Describe a time when you most felt like a scientist?

Is there anything else you want me to know or to share with me?