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Anna Pathammavong

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## Abstract

Our motivation for engaging in certain behaviors, like the metacognitive process, is driven by the type of achievement goals we set for ourselves. Reflective writing is critical in the metacognitive process because it engages how we communicate our thoughts to others. In this study we classified twenty-one future elementary school educators as having set either mastery achievement goals or performance achievement goals for themselves in a science teaching methods course. Our study focused on the relationship between the type of achievement goals each student identified with and their engagement in metacognitive processes following specific learning activities. We hypothesized that students who were classified with mastery achievement goals would engage in the metacognitive process as measured by their reflective writing and that they understand the importance of a 3D science approach to teaching based on demonstration of competence in their essays . To determine if there was a relationship, a survey about achievement goals was conducted on the first day of class, and daily learning reflections and reflective essays were collected and analyzed over the course of the semester. Our hypothesis was mostly supported and indicated that a larger percent of students with mastery achievement goals were engaged in the reflective process after learning activities. Students who were engaged in the reflective process were better able to demonstrate their understanding of the 3D approach to teaching different science topics in class with a summative assessment compared to students who were disengaged.



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EXAMINATION OF THE RELATIONSHIP BETWEEN BIOT 303 STUDENTS' ACHIEVEMENT GOALS AND METACOGNITIVE REFLECTIVE WRITING

By

Anna Pathammavong

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Our motivation for engaging in certain behaviors, like the metacognitive process, is driven by the type of achievement goals we set for ourselves. Reflective writing is critical in the metacognitive process because it engages how we communicate our thoughts to others. In this study we classified twenty-one future elementary school educators as having set either mastery achievement goals or performance achievement goals for themselves in a science teaching methods course. Our study focused on the relationship between the type of achievement goals each student identified with and their engagement in metacognitive processes following specific learning activities. We hypothesized that students who were classified with mastery achievement goals would engage in the metacognitive process as measured by their reflective writing and that they understand the importance of a 3D science approach to teaching based on demonstration of competence in their essays. To determine if there was a relationship, a survey about achievement goals was conducted on the first day of class, and daily learning reflections and reflective essays were collected and analyzed over the course of the semester. Our hypothesis was mostly supported and indicated that a larger percent of students with mastery achievement goals were engaged in the reflective process after learning activities. Students who were engaged in the reflective process were better able to demonstrate their understanding of the 3D approach to teaching different science topics in class with a summative assessment compared to students who were disengaged.

# Introduction

## Motivation and Self-Regulated Learning

Our motivations and how we communicate are central in the process of developing knowledge, in teaching, and in our everyday interactions. Motivational state plays a major role in how students approach learning and achievement in the classroom, as goal theorists view achievement as regulated by goals that are situation specific (Lieberman and Remedios, 2007). Therefore, a student's goals may be different depending on their circumstances. For example, a student may have different goals to do well in a course that is required for their major versus for a course that is not required for their major. Some goal theorists believe that there are two different motives for achievement: mastery achievement goals and performance achievement goals (Lüftenegger et al., 2016). Mastery achievement goals indicate that there are inherent benefits in mastering a task. For instance, students may demonstrate a mastery goal when completing a class because they have genuine interest in the subject, allowing them to develop competence and utilize the material that is taught *(intrinsic)* (Korn and Elliot, 2016). With performance achievement goals, students may want to achieve in order to attain an external goal and demonstrate competence rather than develop. In this case, students may register for a course and have plans to pass the course not because of their goal to master, but only because it is a graduation prerequisite *(extrinsic)* (Elliot and McGregor, 2001). If students partake in self-regulated learning, an active and constructive learning process, this will allow them to strive for the goals they set for themselves in a course through their motivation and behavior, reflection, and metacognition (Atasoy, 2015).
Self-regulated learning emphasizes metacognitive strategies in the classroom, which engages

learning through oneself and initiates “thinking about thinking” (McDowell, 2019). Being able to understand how our motivations and goals are relevant to the reflective writing process used in classrooms can spark conversation in the field of learning/teaching.

**Metacognitive Reflective Writing**

Metacognition is an important component in science learning and discourse because, through reflective writing, students can reflect on their prior knowledge, their thought process about a scientific concept, and their cognitive strengths and weaknesses. (Wallace, 2004). Reflective writing facilitates metacognition and allows students to make sense of scientific concepts and language in their classes (Balgopal and Montplaisir, 2011). Reflective writing is both a process of critical thinking and a product that makes that critical thinking process visible to the reader (Bean, 2011). Visible thinking can be conveyed through explanations, demonstrations, drawing, writing, and several other methods. It is beneficial that teachers as well as students should think, be aware of their thinking, organize and clarify their thinking, and then share their thinking in some form (Ritchhart et al., 2011). From a philosophical standpoint, students are “writing to learn” and building their understanding of and their ability to use scientific concepts and terminology. Having students write reflectively may aid them in building on their knowledge by asking them to describe what they learned in their own words, applying new concepts and terminology. Students can make meaning about a scientific topic and track how these ideas and their understanding have evolved over the course of the science unit (Balgopal et al., 2012). When they reflect, they are also establishing a habit of metacognition in order to understand complex ideas learned in class. Allowing self-evaluation and reflection of an individual's experiences (why are we doing what we are doing in class?) may make understanding these concepts much easier (Hume, 2009). Being able to gauge one's construction of knowledge is important, especially with reflective writing, since this tool is practiced in the classroom to help strengthen the scientific literacy of students. Therefore, a student who can identify their knowledge gaps and ask questions about any obscure content will most likely demonstrate and improve their scientific literacy (Costa and Kallick, 2008).

**Scientific Literacy and Discourse**

Scientific literacy is defined as different modes of effective communication within the scientific community (Norris and Phillips, 2003). Scientific literacy consists of effective speaking, reading, listening, writing, and locating reliable information within the context of scientific discourse (Seddon, 2017). It is ideal when attending a scientific research seminar, that the speaker should effectively speak to audience members who more than likely are members of a scientific research community. Likewise, an audience member at this same research seminar should be able to comprehend the language of the research community and what the speaker is saying to optimize transfer of knowledge. This relationship requires not only an understanding of the technical words commonly used in discourse within the community but also proper syntax associated with communication in the community (Wallace, 2004). The ability to effectively extract a particular text written for and submitted to the scientific community requires decoding the meaning in that text. The same is true as a writer in the sense that an author needs to encode meaning in such a way that the intended readers can comprehend the text. Two challenges that students face in a science classroom are learning how to make meaning of scientific terminology (i.e., decoding meaning) and learning how to properly use scientific terminology (i.e., encoding meaning) when engaging in scientific discourse (Pushkin, 1997). They can bolster better understanding of the scientific topics they are learning in class by communicating their knowledge through reflective writing (Costa and Kallick, 2008). To address these challenges, the process of reflective writing has been used as a tool in some science classrooms to develop understanding of scientific concepts.

**Need for Study**

This study addressed the following research questions:

- Are students with mastery achievement goals more engaged in the reflective process after a learning activity compared to students with performance goals?
- Are students who are engaged in the reflective process able to better demonstrate their understanding of the scientific topics in their reflective essay compared to students who were disengaged?

The group of students who participated in this study were a part of the BIOT 303 Life Science for Elementary Teachers course, a prerequisite for future educators. With the students who are enrolled in BIOT 303, we want them to understand their dual role to develop their scientific literacy as a student and as a teacher. They should understand how reflective writing to promote metacognition will aid in their success in future careers/endeavors (in this research group’s case, becoming teachers) and how constant application of their knowledge will help them realize their strengths and weaknesses in a particular subject. Students in BIOT 303 who are able to learn and reflect from a learning experience and successfully demonstrate understanding of a topic should benefit from the course the most, indicating that they are also able to apply their knowledge when teaching a science course. Results from this study could allow us to determine how and whether students will buy into the idea that reflective writing is a useful tool in the development of their scientific literacy and learning/teaching in class.

The purpose of this study was to determine if there was a relationship between the type of achievement goals these prospective elementary school teachers set for this course and their level of engagement in the metacognitive process following learning activities in class. We hypothesized that students who were motivated by mastery achievement goals would engage in the metacognitive process as measured by their reflective writing. We also hypothesized that students who were engaged in the reflective process would understand the importance of a 3D science approach to teaching as measured by their demonstration of competence in their reflective essays.

*Students were categorized into two groups (Fig. 1):*

**Group 1: Students with mastery achievement goals**

Students who viewed the class as an opportunity to learn more about and practice learning and teaching. Students with the first identity have set **mastery achievement goals** so they could seek to master a topic or skill (e.g., thinking deeply about a scientific topic and making that thinking visible in reflective writing) (Ritchhart et al., 2011).

**Group 2: Students with performance achievement goals**

Students who viewed the class as one that fulfills a requirement to be able to teach. Students that have the latter identity have set **performance achievement goals** so they could seek to complete a task (e.g., turn in the reflective writing assignments to make sure they get credit in order to pass the class) (Yilmaz Soylu et al., 2017).

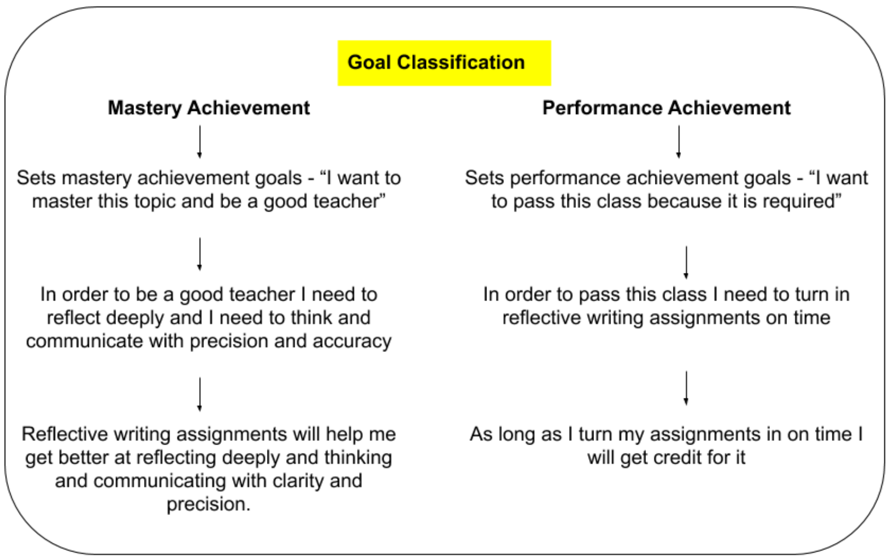


**Figure 1**. A modified version of Elliot and McGregor's achievement goal framework (Elliot and McGregor, 2001) as an example in identifying students' achievement goals and how they engage in reflective writing throughout the course.

## Methods

### Participants and De-identification

This study, which received human subjects approval (UHSRC-FY18-19-56), included twenty-one prospective elementary teachers enrolled in one section of the BIOT 303 *Life Science for Elementary Teachers* course. Each participant signed a consent form to ensure that their submitted assignments were de-identified for confidentiality purposes and data analysis. Each ID code was formulated by assigning a random number to the individuals, from 20-41, which was then affixed to the course title (e.g., BIOT303-20). All information and collected data were stored in a password-protected folder. The following items were collected, and data were analyzed through quantitative and qualitative approaches:

**Achievement Goal Questionnaire**

On the first day of class, a twelve-item questionnaire (Fig. 2) originally developed by Elliot and McGregor (2001) was distributed and collected by the primary researcher shortly after completion. Based on responses to the statements in the questionnaire, the compiled data were used to identify the type of achievement goal for each student at the beginning of the semester. Statements 1-6 and 7-12 were divided into two different sets and corresponded to Performance and Mastery achievement goals, respectively. Scoring was based on behavior in relation to the statement on a 7-point Likert-type scale ranging from 1 (Almost Never True) to 7 (Almost Always True). For instance, if a student highly agreed with the first statement that it is important for them to do better than other students, they would fill in the first bubble (7) corresponding to "Almost Always True". The scores of each set of statements (1-6, and 7-12) for each student were averaged. Upon calculating the average score for each set of statements, an initial classification was assigned to each student; those with a higher average of performance achievement scores were assigned with the performance achievement goal classification and the same was done for students with a higher average of mastery achievement goal scores.

| | Shade in the circle that most accurately corresponds to your behavior in relation to the statement | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Statement** | **7) Almost Always True** | **6) Usually True** | **5) Often True** | **4) Occasionally True** | **3) Sometimes But Infrequently True** | **2) Usually Not True** | **1) Almost Never True** |
| **Performance** | It is important for me to be better than other students | | | | | | | |
| | It is important for me to do well compared to others in my courses | | | | | | | |
| | My goal in this course is to get a better grade than most of the other students | | | | | | | |
| | My goal in this course is to avoid performing poorly | | | | | | | |
| | My fear of performing poorly is often what motivates me | | | | | | | |
| | I just want to avoid doing poorly in my courses | | | | | | | |
| **Mastery** | I am often concerned that I may not learn all there is to learn in a class | | | | | | | |
| | Sometimes I am afraid that I may not understand the content of this course as thoroughly as possible | | | | | | | |
| | I worry that I may not learn all that I possibly could in my classes | | | | | | | |
| | I want to learn as much as possible from all my courses | | | | | | | |
| | I desire to completely master the material presented in my courses | | | | | | | |
| | It is important for me to understand the content of my course as thoroughly as possible | | | | | | | |

**Figure 2.** Achievement goal questionnaire. Scoring was based on behavior in relation to the statement on a 7-point Likert-type scale ranging from 1 (Almost Never True*)* to 7 (Almost Always True).

## Reflective Writing Assignments

### *Daily Learning Reflections (DLRs)*

Students' learning experiences in class are enhanced when reflecting on these experiences (Costa & Kallick, 2008). There were 13 DLRs and each one was assigned after specific learning activities every week to allow students to reflect on what they learned from their research during group projects. DLRs served as an indicator of how well students comprehended each learning activity covered in class and provided students with an opportunity to reflect on and make sense of their understanding of the key concepts. DLRs were divided among four different projects (DLRs #1-4, 5-7, 8-10, and 11-13) and following each project, students were assigned to complete a reflective essay (Discussed in the next subsection) to further assess student understanding of the key concepts each learning activity was meant to teach. Each project corresponded to four different Life Science Disciplinary Core Ideas (LS-DCI) as a part of satisfying the Next Generation Science Standards. This is an ideal framework that educators have adopted to teach science and is practiced in the classroom (National Research Council, 2012):

1. **LS1-From Molecules to Organisms: Structures and Processes (LS1-DCI)**
2. **LS2-Ecosystems: Interactions, Energy, and Dynamics (LS2-DCI)**
3. **LS3-Heredity: Inheritance and Variation of Traits (LS3-DCI)**
4. **LS4-Biological Evolution: Unity and Diversity (LS4-DCI)**

Each DLR was a measure of their reflective process as students were provided with prompts tied to a specific learning activity and were assigned to reflect on each prompt:

*1. Learning Activity to Define the Disciplinary Core Idea*

*2. Learning Activity to Model 3D Teaching*

*3. Learning Activity to Uncover K-5 Student Sense Making*

**Example Prompts for DLR #4: Learning Activity to Uncover K-5 Student Thinking**

*LS1-From Molecules to Organisms: Structures and Processes (LS1-DCI)*

Learning Outcome: Demonstrate an understanding of and articulate the importance of the life science disciplinary core idea LS1-From Molecules to Organisms: Structures and Processes (LS1-DCI) for 3D science learning in grades K-6

- What's something new you learned today about how elementary school children make sense of **the structures and processes of living organisms**?
- What still puzzles you about how elementary school children make sense of **the structures and processes of living organisms**?

*DLR Analysis*

There were no specific guidelines given for how and how much to write. After each DLR was submitted and read, it was graded as either “complete” or “incomplete”. A “complete” grade was given if the student was able to show that they made an effort to reflect on what they learned from each learning activity. All DLRs were evaluated regardless of the complete/incomplete grade as each one was classified as either *1) Fully engaged, 2) Mostly engaged, 3) Somewhat engaged, or 4) Disengaged*. In order to be classified into the *Fully engaged* category, students must satisfy all three criteria (Table 1): Reflect with a word count of 200 or more words, address all the prompts that were assigned by making a claim, and elaborating on those claims with evidence by providing examples. Failure to satisfy all three criteria classified students into *Mostly engaged* if they only reflected with 200 or more words and stated claims, *Somewhat engaged* if they only stated claims, or *Disengaged* if none of the criteria were met. An example analysis of a DLR can be found in the *Appendix*.

| **Type of Engagement** | **200 or more words?** | **Clearly, stated claims?** | **Elaborated on claims?** |
|---|---|---|---|
| Fully Engaged | | | |
| Mostly Engaged | | | |
| Somewhat Engaged | | | |
| Disengaged | | | |

**Table 1.** Visual table explaining the relationship between types of engagement and three different criteria of DLR submissions. Green indicated criteria that were satisfied and light red indicated criteria that were not satisfied.

*Reflective Essays*

Reflective essays were four summative assessments that allowed students to reflect on what they have learned about their scientific topics from their projects. Being able to reflectively write in a science course should enhance students' science learning, awareness of the topics being learned, and the strategies regarding their own writing (Levin & Wagner, 2006). These essays focused on whether each student was able to meet the learning outcomes that were set for the course with these scientific topics which were the four different Life Science Disciplinary Core Ideas (LS-DCI). Within each essay, students were given the opportunity to demonstrate their understanding of their learning experiences and expected to respond to four prompts by articulating their understanding about the DCI they learned in class. Each prompt is connected to the ideas of 3D science as an approach to teaching science in the classroom, combining the importance of DCI, Sense Making, Science and Engineering Practices, and Crosscutting Concepts, respectively:

***Prompt 1:*** Be able to explain the importance of the given **DCI** during each project and how it relates to science learning in grades K-5.

***Prompt 2:*** Be able to explain the importance of how K-5 students **make sense** and understand the ideas, experiences, topics discussed of the given DCI and what they learned from their interviews with these students.

***Prompt 3:*** Be able to explain the importance of science and engineering practices (**SEP**) of the given DCI and how it can be used in grades K-5. They should understand the use of asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting models, and constructing explanations and designing solutions.

***Prompt 4:*** Be able to explain the importance of crosscutting concepts (**CC**) of the given DCI and how it can be used in grades K-5. They should understand the use of patterns, systems and system models, energy and matter, and structure and function.

*Reflective Essay Analysis*

An example analysis of a reflective essay can be found in the *Appendix.* Analysis of the reflective essays classified each prompt explanation into three different categories:

**Target Explanation)** The author of the reflective essay is able to clearly articulate their understanding with a claim that responds to the prompt and is supported with examples or evidence.

**Acceptable Explanation)** The author of the reflective essay states a claim in response to the prompt but can do better to articulate their understanding with examples or evidence.

**Unacceptable Explanation)** The author of the reflective essay does not clearly articulate their understanding with a claim that responds to the prompt.

*Making Connections with Reflective Writing Assignments*

During analysis and making connections to data, successful engagement in the metacognitive process is represented if the student was able to reflectively write and build their understanding of four projects through each class session's learning activities. For every project, with LS1-DCI being an exception with two DCI activities and two DLRs, there was one DLR assigned after each learning activity. After each project was complete, we wanted to see if students could further demonstrate their understanding with each LS-DCI and if this understanding was also evident in their reflective essays, ultimately resulting in a target explanation. Each prompt of the reflective essay corresponded to a 3D teaching idea that tied to a particular learning activity and reflection (Table 2).

| Project | Learning Activity | Reflection | Demonstration of Understanding |
|---|---|---|---|
| LS1- From Molecules to Organisms: Structures and Processes | DCI Activity #1 | DLR #1 | Prompt #1 from Reflective Essay for LS1-DCI |
| | DCI Activity #2 | DLR #2 | |
| | 3D Lesson Model for Molecules to Organisms | DLR #3 | Prompt #3 from Reflective Essay for LS1-DCI |
| | | | Prompt #4 from Reflective Essay for LS1-DCI |
| | Interviews and Presentations with K-5 Students | DLR#4 | Prompt #2 from Reflective Essay for LS1-DCI |
| LS2 - Ecosystems: Interactions, Energy, and Dynamics | DCI Activity | DLR #5 | Prompt #1 from Reflective Essay for LS2-DCI |
| | 3D Lesson Model for Ecosystems | DLR #6 | Prompt #3 from Reflective Essay for LS1-DCI |
| | | | Prompt #4 from Reflective Essay for LS2-DCI |
| | Interviews and Presentations with K-5 Students | DLR#7 | Prompt #2 from Reflective Essay for LS2-DCI |
| LS3 - Heredity: Inheritance and Variation of Traits | DCI Activity | DLR #8 | Prompt #1 from Reflective Essay for LS3-DCI |
| | 3D Lesson Model for Heredity | DLR #9 | Prompt #3 from Reflective Essay for LS3-DCI |
| | | | Prompt #4 from Reflective Essay for LS3-DCI |
| | Interviews and Presentations with K-5 Students | DLR #10 | Prompt #2 from Reflective Essay for LS3-DCI |
| LS4 - Biological Evolution: Unity and Diversity | DCI Activity | DLR #11 | Prompt #1 from Reflective Essay for LS4-DCI |
| | 3D Lesson Model for Biological Evolution | DLR #12 | Prompt #3 from Reflective Essay for LS4-DCI |
| | | | Prompt #4 from Reflective Essay for LS4-DCI |
| | Interviews and Presentations with K-5 Students | DLR #13 | Prompt #2 from Reflective Essay for LS4-DCI |

**Table 2**. Comprehensive table displaying the relationship between the four sets of LS-DCI projects, learning activities, DLRs, and reflective essay prompts.

## Results

### Identification of the Type of Achievement Goals

After collecting questionnaire data using the survey from Figure 2, out of 21 students in the research group, there were 13 students who had a higher average score with mastery achievement goals and 8 students who had a higher average score with performance achievement goals. Students classified as having performance achievement goals scored an average of 0.7 points higher with performance statements than mastery statements. Students classified as having mastery achievement goals scored an average of 1.2 points higher with mastery statements than performance statements (Fig. 3).

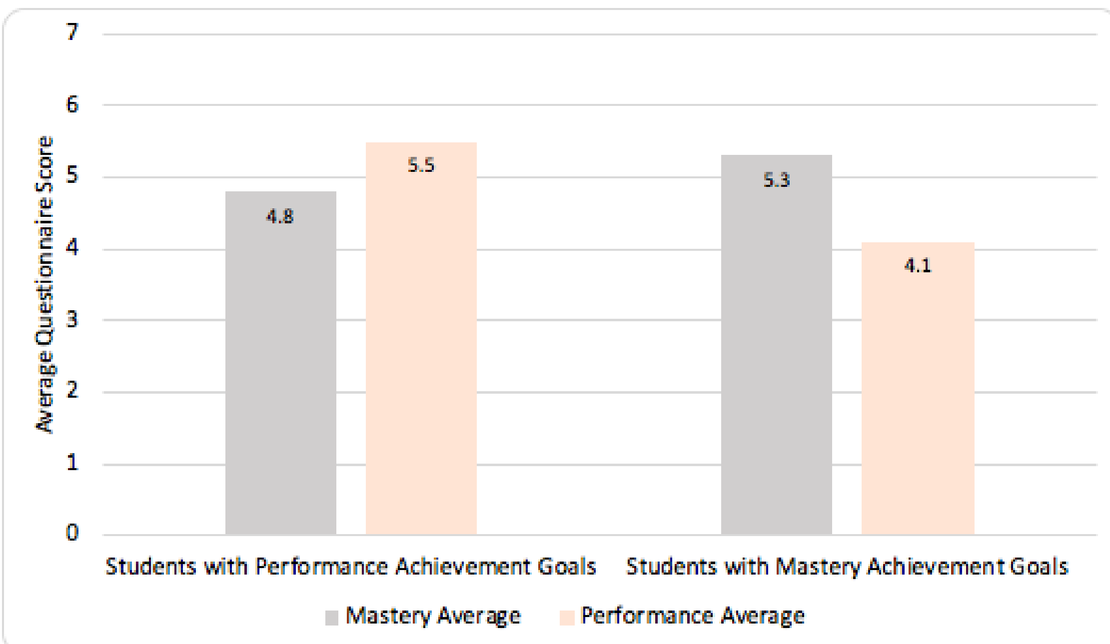


**Figure 3.** The average scores for students in each group with mastery and performance achievement goals as determined from Figure 2 achievement goal questionnaire.

**Engagement in the Reflective Process Following Learning Activities for LS1-From Molecules to Organisms: Structures and Processes**

We wanted to know if students with mastery achievement goals would be more engaged in the reflective process for LS1-DCI than students with performance goals. We determined the level of engagement in the reflective process after the associated learning activity from LS1-DCI for each student and then calculated the percent of students engaged from both categories. Figure 4 shows that a larger percentage of students with mastery achievement goals were highly or mostly engaged in the reflective process after the first DCI learning activity when compared to students with performance achievement goals. A similar pattern was seen with engagement in the reflective process after the other three learning activities as well. Forty-six percent of the students who were in the mastery achievement goal category were engaged in the reflective process after DCI Activity #1, compared to 38% of the students in the performance achievement goal category who were engaged. Fifty-four percent of the students who were in the mastery achievement goal category were engaged in the reflective process after DCI activity #2, compared to 25% of the students in the performance achievement goal category who were engaged. Forty-six percent of the students who were in the mastery achievement goal category were engaged in the reflective process after the 3D Science Lesson Model, compared to 13% of the students in the performance achievement goal category who were engaged. Sixty-nine percent of the students who were in the mastery achievement goal category were engaged in the reflective process following their Interviews and Presentations with K-5 students, compared to 63% of the students in the performance achievement goal category who were engaged. Overall, students with mastery achievement goals were more engaged in the reflective process for LS1-DCI than students with performance goals.

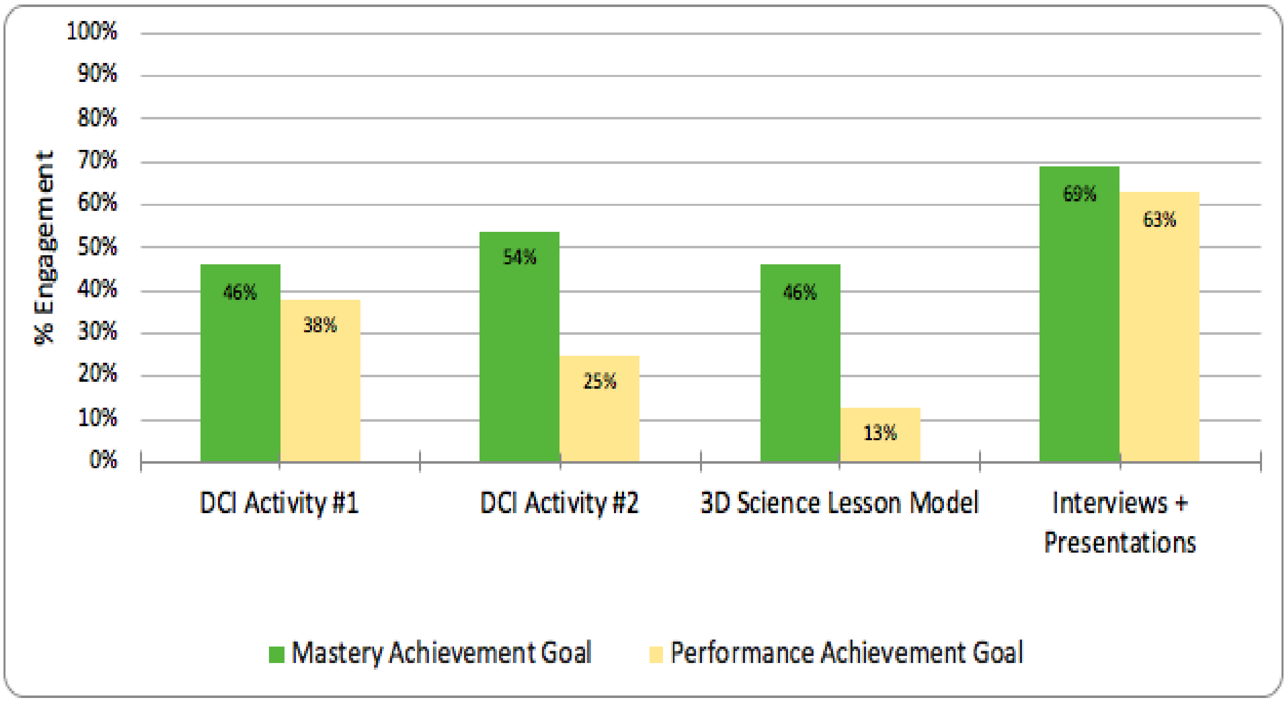


**Figure 4.** Engagement in the reflective process after learning activities from students with mastery achievement goals and performance achievement goals for LS1-From Molecules to Organisms: Structures and Processes.

**Engagement in the Reflective Process Following Learning Activities for LS2-Ecosystems: Interaction, Energy, and Dynamics**

We wanted to know if students with mastery achievement goals would be more engaged in the reflective process for LS2-DCI than students with performance goals. We determined the level of engagement in the reflective process after the associated learning activity from LS2-DCI for each student and then calculated the percent of students engaged from both categories. Figure 5 shows that 62% of the students who were in the mastery achievement goal category were engaged in the reflective process after the DCI Activity, compared to 50% of the students in the performance achievement goal category who were engaged. Forty-six percent of the students who were in the mastery achievement goal category were engaged in the reflective process after the 3D Science Lesson Model, which was actually less, compared to 50% of the students in the performance achievement goal category who were engaged. Seventy-seven percent of the students who were in the mastery achievement goal category were engaged in the reflective process following their Interviews and Presentations with K-5 students, compared to 50% of the students in the performance achievement goal category who were engaged. Overall, students with mastery achievement goals were more engaged in the reflective process for LS2-DCI than students with performance goals. Although, with the 3D Science learning activity, students with performance goals were slightly more engaged in the reflective process. There was no change with percent engagement after each learning activity for individuals with performance goals.

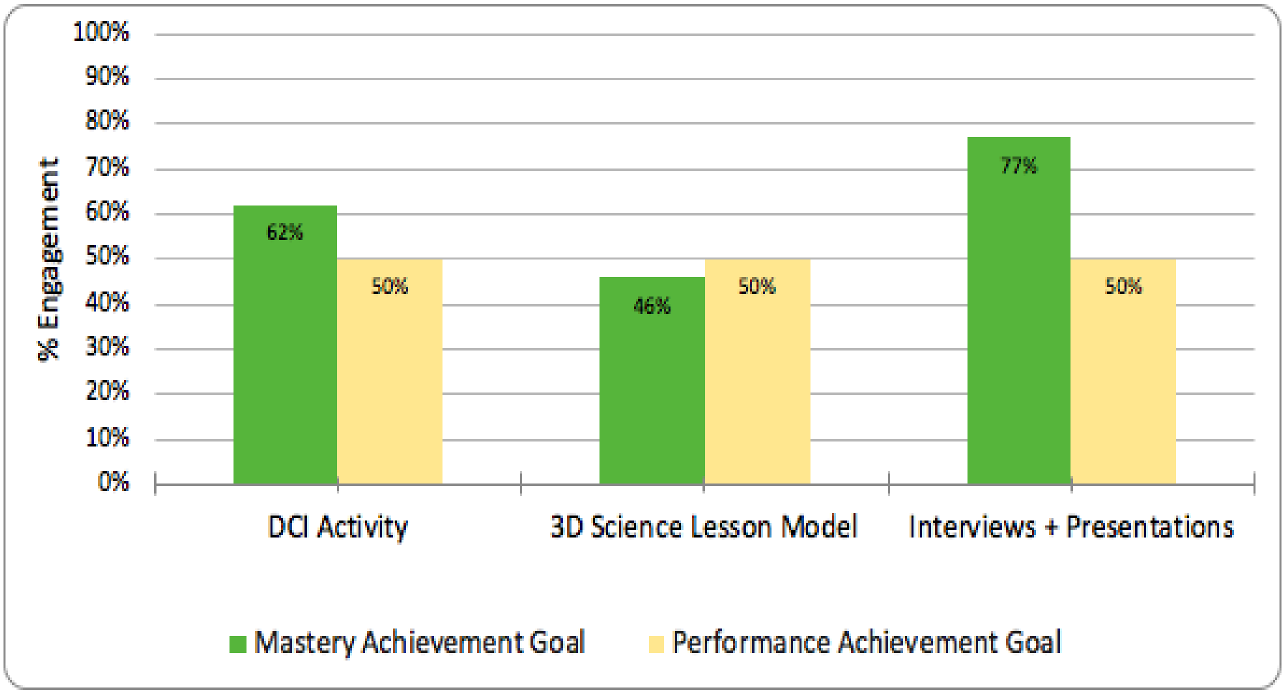


**Figure 5.** Engagement in the reflective process after learning activities from students with mastery achievement goals and performance achievement goals for LS2-Ecosystems: Interaction, Energy, and Dynamics.

**Engagement in the Reflective Process Following Learning Activities for LS3-Heredity: Inheritance and Variation of Traits**

We wanted to know if students with mastery achievement goals would be more engaged in the reflective process for LS3-DCI than students with performance goals. We determined the level of engagement in the reflective process after the associated learning activity from LS3-DCI for each student and then calculated the percent of students engaged from both categories. Figure 6 shows that 46% of the students who were in the mastery achievement goal category were engaged in the reflective process after the DCI activity, compared to 38% of the students in the performance achievement goal category who were engaged. Fifty-four percent of the students who were in the mastery achievement goal category were engaged in the reflective process after the 3D Science Lesson Model, compared to 38% of the students in the performance achievement goal category who were engaged. Forty-six percent of the students who were in the mastery achievement goal category were engaged in the reflective process following their Interviews and Presentations with K-5 students, compared to 13% of the students in the performance achievement goal category who were engaged. Overall, students with mastery achievement goals were more engaged in the reflective process for LS3-DCI than students with performance goals.

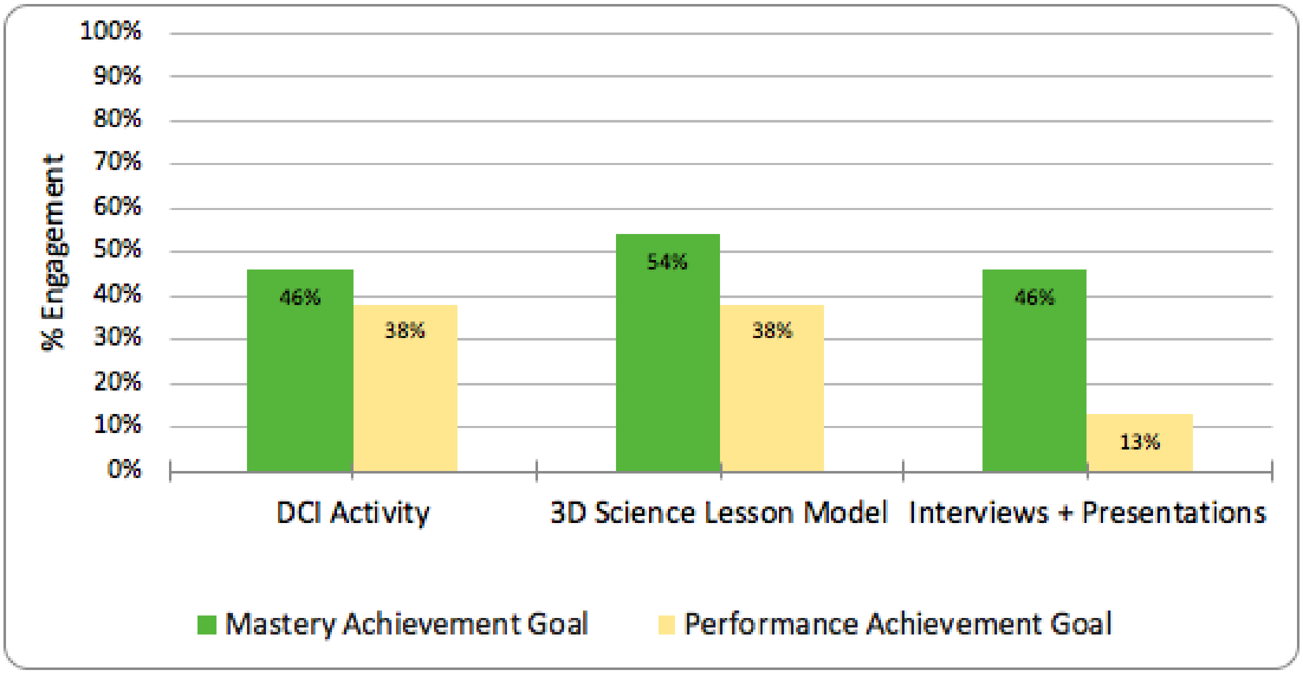


**Figure 6.** Engagement in the reflective process after learning activities from students with mastery achievement goals and performance achievement goals for LS3-Heredity: Inheritance and Variation of Traits

**Engagement in the Reflective Process Following Learning Activities for LS4-Biological Evolution: Unity and Diversity**

We wanted to know if students with mastery achievement goals would be more engaged in the reflective process for LS4-DCI than students with performance goals. We determined the level of engagement in the reflective process after the associated learning activity from LS4-DCI for each student and then calculated the percent of students engaged from both categories. Figure 7 shows that 31% of the students who were in the mastery achievement goal category were engaged in the reflective process after the DCI activity, compared to 25% of the students in the performance achievement goal category who were engaged. Thirty-one percent of the students who were in the mastery achievement goal category were engaged in the reflective process after the 3D Science Lesson Model, compared to 13% of the students in the performance achievement goal category who were engaged. Fifty-four percent of the students who were in the mastery achievement goal category were engaged in the reflective process following their Interviews and Presentations with K-5 students, compared to 38% of the students in the performance achievement goal category who were engaged. Overall, students with mastery achievement goals were more engaged in the reflective process for LS4-DCI than students with performance goals.

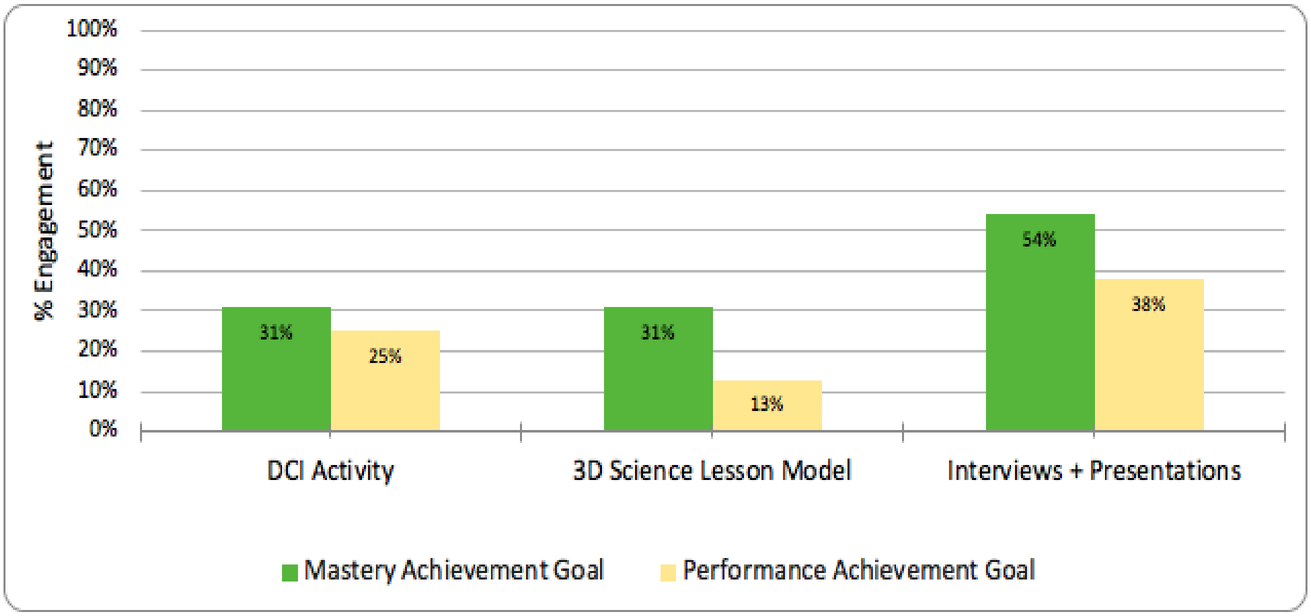


**Figure 7.** Engagement in the reflective process after learning activities from students with mastery achievement goals and performance achievement goals for LS4-Biological Evolution: Unity and Diversity.

**Engagement in the Reflective Process For All Four (LS1-LS4) Projects**

We wanted to know if students with mastery achievement goals would be more engaged in the reflective process than students with performance goals over the course of the semester. The average percent (%) of engagement in the reflective process for all learning activities after each project were calculated. The average percent of engagement in the reflective process declined over the course of the semester for both groups (Fig. 8). Overall, students with mastery achievement goals were more engaged in the reflective process for all projects over the course of the semester than students with performance achievement goals.

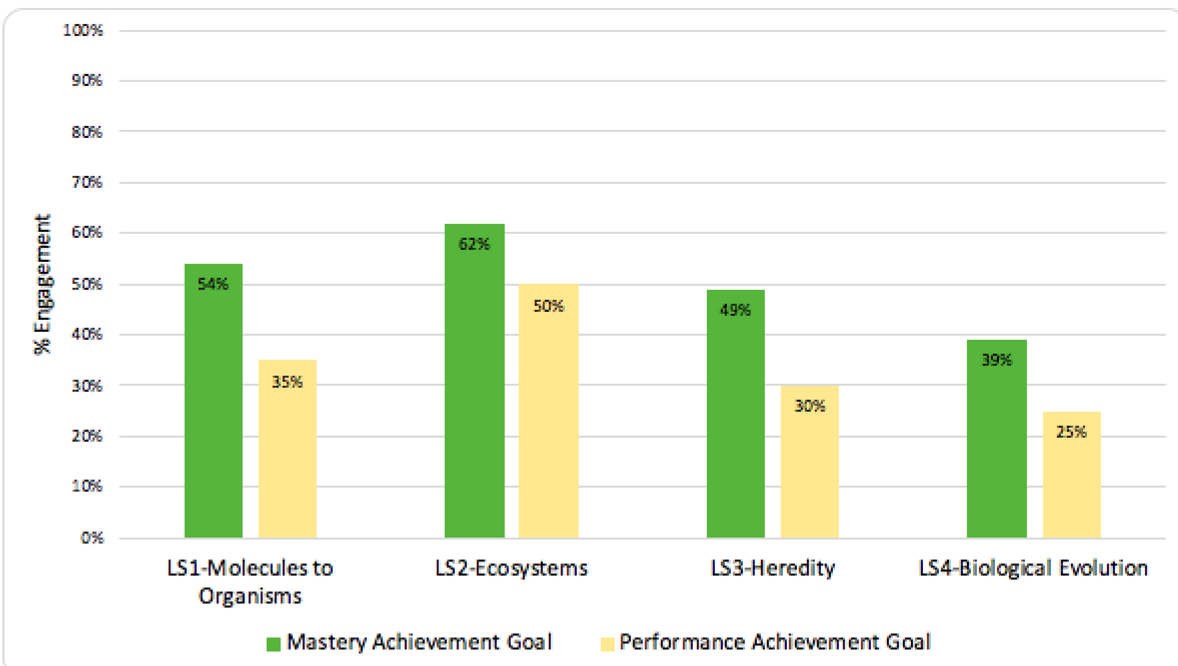


**Figure 8.** Average percent (%) engagement in the reflective process after learning activities from students with mastery achievement goals and performance achievement goals for each project.

**Reflective Essay to Assess Understanding of the Disciplinary Core Ideas**

We wanted to know if students engaged in the reflective process were able to better demonstrate their understanding of the Disciplinary Core Ideas in their reflective essay compared to students who were disengaged. Students were assigned to submit a reflective essay to demonstrate their understanding of the key concepts they were expected to learn throughout the project. Students were grouped according to whether or not they were engaged in the reflective process following the learning activity of each project. Among each group, the percent of students with a target or acceptable explanation were calculated. Figure 9 shows that 78% percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the DCI for LS1-From Molecules to Organisms, compared to 50% of the students who were disengaged in the reflective process. Sixty-seven percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the DCI for LS2-Ecosystems, compared to 33% of the students who were disengaged in the reflective process. Eighty-two percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the DCI for LS3-Heredity compared to 60% of the students who were disengaged in the reflective process. Seventy-three percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the DCI for LS4-Biological Evolution compared to 67% of the students who were disengaged in the reflective process. Overall, students engaged in the reflective process were able to better demonstrate their understanding of the Disciplinary Core Ideas in their reflective essay compared to students who were disengaged.

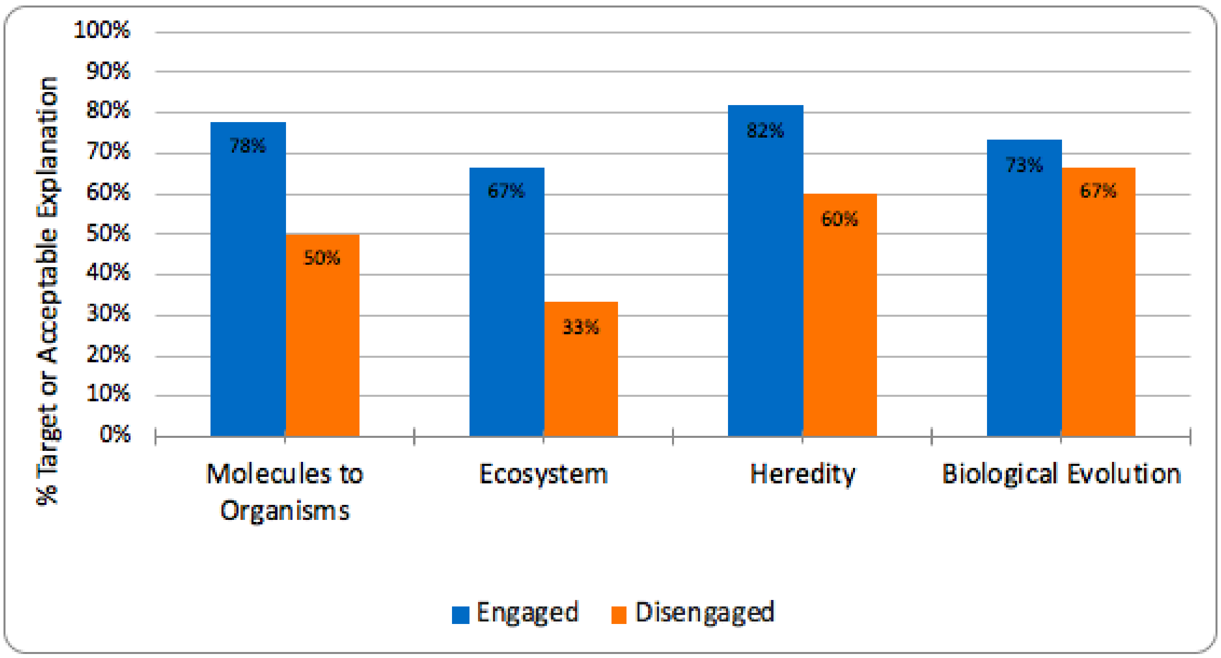


**Figure 9.** Type of engagement in the reflective process of DCI activity for each project and percent (%) of students who reflected with a target or acceptable explanation reflective essay prompt for explaining the DCI.

**Reflective Essay to Assess How K-5 Students Make Sense of the DCI**

We wanted to know if students engaged in the reflective process were able to better demonstrate their understanding of how K-5 students make sense of the DCI in their reflective essay compared to students who were disengaged. Students were assigned to submit a reflective essay to demonstrate their understanding of the key concepts they were expected to learn throughout the project. Students were grouped according to whether or not they were engaged in the reflective process following the learning activity of each project. Among each group, the percent of students with a target or acceptable explanation were calculated. Figure 10 shows that 71% percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood how K-5 students make sense of the DCI for LS1-From Molecules to Organisms, compared to 45% of the students who were disengaged in the reflective process. Seventy-one percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood how K-5 students make sense of the DCI for LS2-Ecosystems, compared to 55% of students who were disengaged in the reflective process. Seventy-one percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood how K-5 students make sense of the DCI for LS3-Heredity, while also 71% of the people who were disengaged in the reflective process demonstrated the same. Sixty percent of the students who were engaged in the reflective process following the learning activity did not demonstrate that they understood how K-5 students make sense of the DCI for LS4-Biological Evolution, while 82% of the people that were disengaged in the reflective process did. Students engaged in the reflective process were able to better demonstrate their understanding of how K-5 students make sense of the DCI in their reflective essays for LS1-From Molecules to Organisms and LS2-Ecosystems. There was no difference for students who were engaged vs. disengaged in the reflective process for LS3-Heredity. Students disengaged in the reflective process were able to better demonstrate their understanding of how K-5 students make sense of the DCI in their reflective essay for LS4-Biological Evolution. Students engaged in the reflective process showed a steady trend for the first three projects, followed by a decrease in the last project. Students disengaged in the reflective process showed an increasing trend for all four projects.

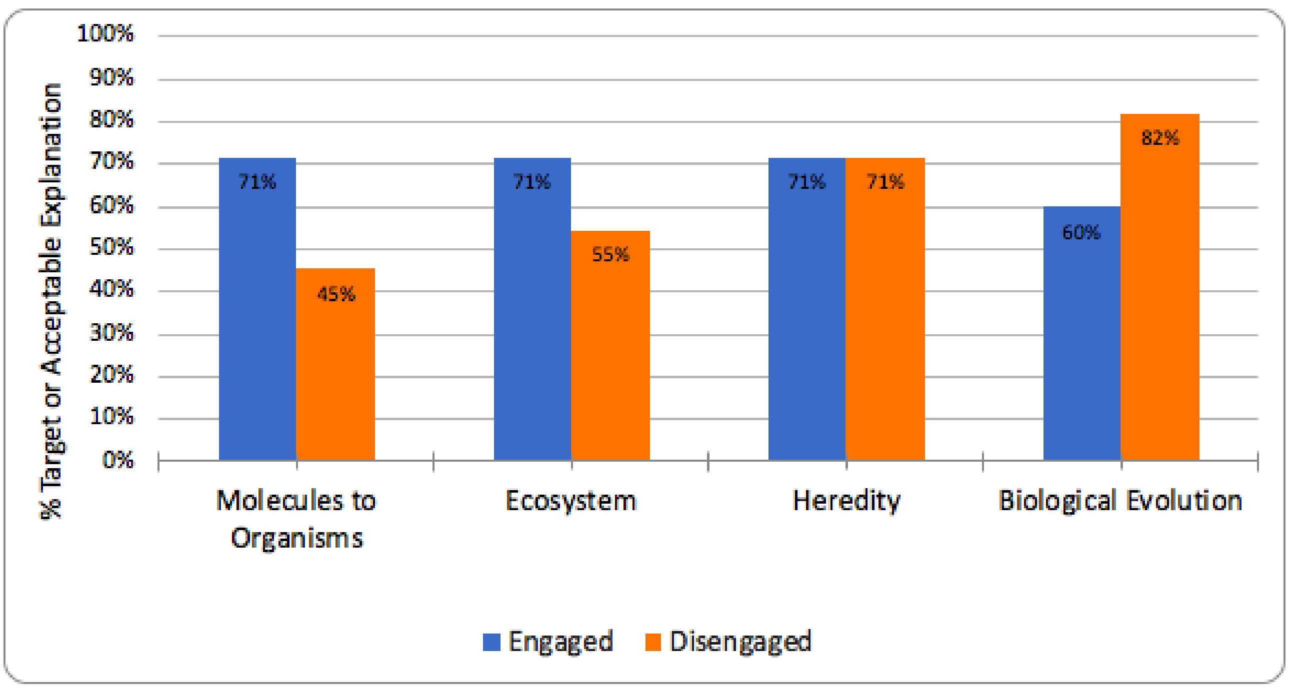


**Figure 10.** Type of engagement in the reflective process of K-5 student sense making for each project and percent (%) of students who reflected with a target or acceptable explanation for reflective essay prompt on how K-5 students make sense of the DCI.

**Reflective Essay to Assess How Science and Engineering Practices Build Understanding of the DCI**

We wanted to know if students engaged in the reflective process were able to better demonstrate their understanding of the Science and Engineering Practices in their reflective essay compared to students who were disengaged. Students were assigned to submit a reflective essay to demonstrate their understanding of the key concepts they were expected to learn throughout the project. Students were grouped according to whether or not they were engaged in the reflective process following the learning activity of each project. Among each group, the percent of students with a target or acceptable explanation were calculated. Figure 11 shows that 43% percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the SEP for LS1-From Molecules to Organisms, compared to 14% of the people that were disengaged in the reflective process. Fifty percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the SEP for LS2-Ecosystems, compared to 9% of the people that were disengaged in the reflective process. Seventy percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the SEP for LS3-Heredity, compared to 36% of the people that were disengaged in the reflective process. Forty-three percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the SEP for LS4-Biological Evolution, compared to 36% of the people that were disengaged in the reflective process. Students engaged in the reflective process were able to better demonstrate their understanding of the SEP in their reflective essay compared to students who were disengaged.

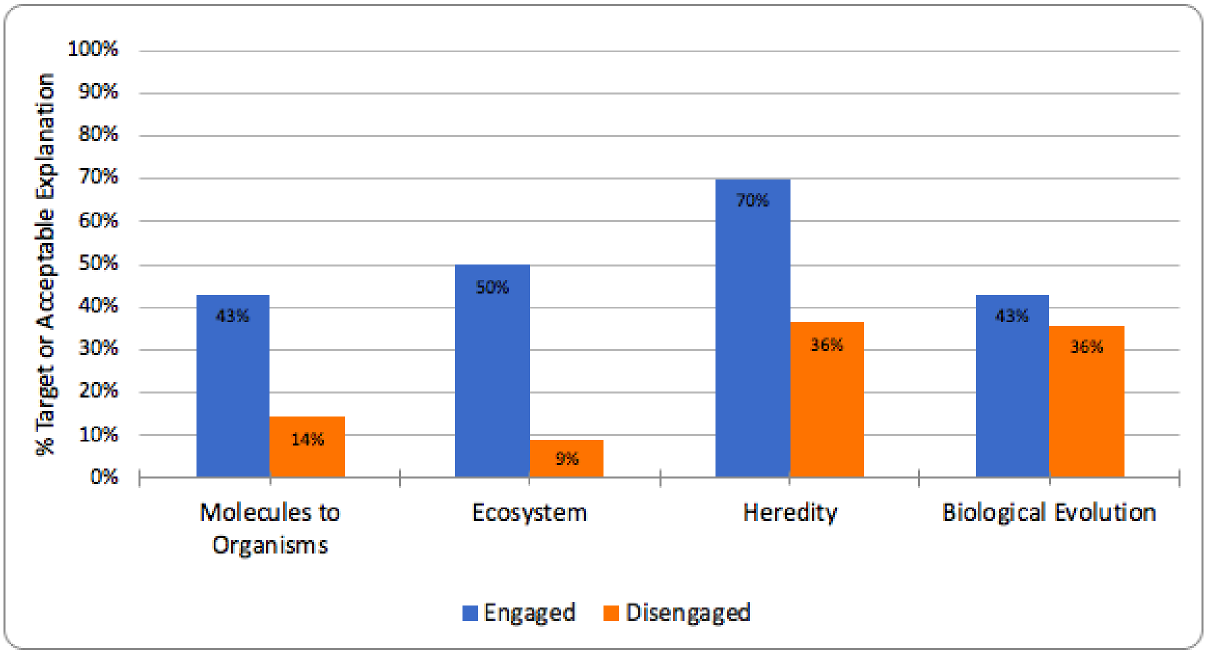


**Figure 11.** Type of engagement in the reflective process of 3D science lesson model for each project and percent (%) of students who reflected with a target or acceptable explanation for reflective prompt essay on how science and engineering practices help students build their understanding of DCI.

**Reflective Essay to Assess How Crosscutting Concepts Build Understanding of the DCI**

We wanted to know if students engaged in the reflective process were able to better demonstrate their understanding of Crosscutting Concepts in their reflective essay compared to students who were disengaged. Students were assigned to submit a reflective essay to demonstrate their understanding of the key concepts they were expected to learn throughout the project. Students were grouped according to whether or not they were engaged in the reflective process following the learning activity of each project. Among each group, the percent of students with a target or acceptable explanation were calculated. Figure 12 shows that 29% percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the CC for LS1-From Molecules to Organisms, compared to 7% of the people that were disengaged in the reflective process. Fifty percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the CC for LS2-Ecosystems, compared to 36% of the people that were disengaged in the reflective process. Sixty percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the CC for LS3-Heredity, compared to 27% of the people that were disengaged in the reflective process. Fifty-seven percent of the students who were engaged in the reflective process following the learning activity demonstrated they understood the CC for LS4-Biological Evolution, compared to 29% of the people that were disengaged in the reflective process. Students engaged in the reflective process were able to better demonstrate their understanding of the CC in their reflective essay compared to students who were disengaged.

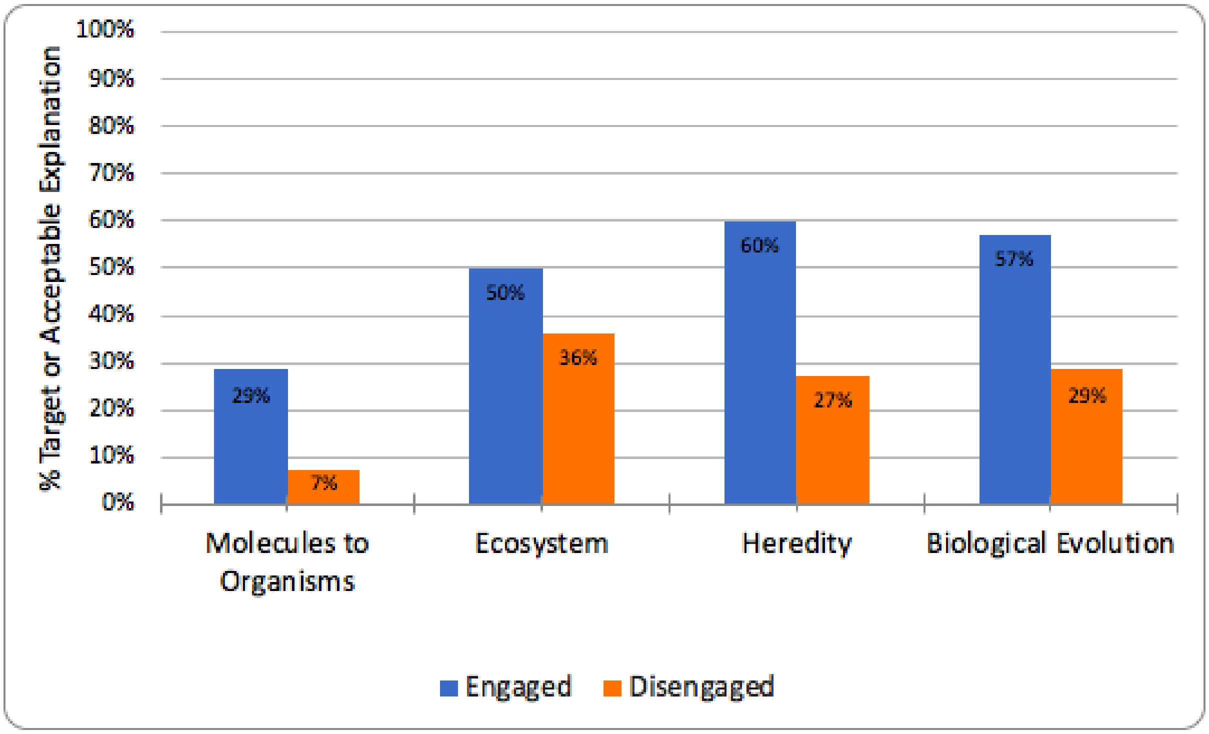


**Figure 12.** Type of engagement in the reflective process of 3D science lesson model for each project and percent (%) of students who reflected with a target or acceptable explanation for reflective essay prompt on how crosscutting concepts help students build their understanding of DCI.

**Discussion**

The purpose of this study was to examine if there was a relationship between the type of achievement goals of prospective elementary school teachers and their level of engagement in the metacognitive process following learning activities in class and level of understanding of key science teaching concepts. We were trying to get a sense of the level of engagement of that process from the written product these students submitted, and hypothesized that the type of achievement goal would correlate with their participation in reflective writing (e.g., how deeply they reflect/makes thinking visible). In order to determine if there was a relationship, a survey was conducted to determine the type of achievement goals students identified with in the course, DLRs and reflective essays were collected and analyzed over the semester to measure level of engagement in the reflective process following a specific learning activity, and to determine level of understanding of key science teaching concepts.

Our hypothesis, that students who were classified with mastery achievement goals would engage in the writing process more and understand the importance of the scientific topics taught in class, was mostly supported. Our results revealed that, over the course of the semester, a larger percentage of students with mastery achievement goals were mostly more engaged in the reflective process after each learning activity compared to students with performance achievement goals. Figure 4 shows that a higher percentage of students with mastery achievement goals were engaged in the reflective process after each learning activity for the Structures and Processes of Organisms Project (LS1-DCI) compared to the percentage of students with performance achievement goals who were engaged in the metacognitive process following these same learning activities. A similar trend was observed in the Heredity Project (LS3-DCI) and the Biological Evolution Project (LS4-DCI) (Figures 6 and 7 respectively). Figure 5 displayed a different trend with the Ecosystems Project (LS2-DCI) as students with performance goals had a slightly larger percentage of student engagement in the reflective process after the 3D Science Lesson Model learning activity. Although, there was only a 4% difference between the two groups. We noticed that there were no changes with percent engagement (50%) after each learning activity for individuals with performance goals for LS2-DCI. The trend in these graphs show that students with performance achievement goals improved in their engagement of the reflective process for LS2-DCI, but did not follow through with their engagement after learning activities for LS3-DCI and LS4-DCI. This suggests that maybe these students did not buy into the idea that reflective writing is a useful tool in the development of their scientific literacy and learning/teaching in class. Figure 8 displayed a declining trend of each project over the course of the semester for the average percent of engagement in the reflective process of both groups. This trend could indicate that as the semester continued, students also invested more time in other courses aside from BIOT 303, affecting percent of engagement in their reflections.

Our second hypothesis, that students who were engaged in the reflective process would better demonstrate their understanding of the scientific topics in their reflective essay compared to students who were disengaged, was mostly supported. Our results revealed that over the course of the semester, students who engaged in the reflective process following the learning activities (as measured through the DLRs) were able to convey a deeper understanding about 3D teaching and applied this knowledge with an acceptable or target explanation in their reflective essays. Figure 9, 11, and 12 displayed similar trends as a higher percentage of students engaged in the reflective process following the learning activities provided acceptable/target explanations in each of their reflective essay prompts for DCI, SEP, and CC compared to the percentage of students who were not engaged in the reflective process following the learning activities. Although, Figure 10 displayed a different trend for K-5 Student Sense Making. We noticed that for the first three projects, 71% of the students who were engaged in the reflective process after their learning activities provided target or acceptable explanations in their reflective essays. Also, 71% of students who were disengaged after their learning activity had a target or acceptable explanation with the third project, LS3-Heredity. The last project with LS4-Biological Evolution also displayed a higher percentage of disengaged students (82%) provided target/acceptable explanations compared to the engaged group (60%). Students received instructor feedback after each reflective essay. Therefore, these data could indicate particularly with K-5 Student Sense Making that students who were disengaged in the reflective process after a learning activity did a better job at the end of the semester, which translated into them improving on their explanation and being able to reflect on the 3D teaching idea in their reflective essay a fourth time.

**Limitations and Future Directions**

One limitation in the study is that the sample size used to collect and interpret data was small (n=21). This limited the ability to do statistical tests or find statistical differences in data. When and if continuing research, more students should be recruited and involved in the study as this will increase sample data to be used when comparing data.

Achievement goal questionnaires may not be sufficient to determine a student's achievement goal identity. Classifying students with mastery or performance achievement goals can be limited. Therefore, generating another assessment and/or identifying alternative methods of classification and delving into more literature to see what other researchers have done may be beneficial. Being able to have various metrics used for analysis can yield more comprehensive results. For example, one study examined the relationships between writing achievement goals, self-efficacy, affect, and writing performance as writing achievement goal surveys were administered and data was analyzed, students self reported their writing grades, and their scores from a state-wide assessment were examined (Yilmaz Soylu et al., 2017).

Also, the achievement goal questionnaire does not account for the type of goals that students would have in a course if it were not required, as BIOT 303 was required for these students. If the class was not mandatory or required as a program prerequisite, perhaps students would be more inclined to score toward performance achievement goals and this would affect their level of engagement in the reflections. It would be helpful to compare the data from this study to a similar study that researched students in an elective or non-required class for their major/field of study.

Not having guidelines with exact word count limit and structure of how prompts should be addressed limited how students could have responded in their assignments. If they were not sure that stating a claim was enough to answer the given prompt, they either included examples to back their claim or did not at all because they felt it was not required. In the future, assignments with more guidelines should be considered and analyzed to determine if there is a difference. Because writing enables students to metacognitively reflect, having writing prompts can encourage them to ponder on issues more than they would without guidance (Turner & Broemmel, 2006).

**Summary and Implications**

We wanted to demonstrate to students how our motivations and achievement goals are relevant to the metacognitive reflective writing process, and how this could be important in developing knowledge, in learning, teaching, and in our everyday interactions. Reflective writing is a critical thinking process and allows students to strengthen scientific literacy skills by discussing the topics, concepts, and theories they learn more than students who are not engaged in these types of activities (Shanahan, 2004). There are many factors to consider when conducting this type of study again including a larger sample size, the use of various other metrics to measure engagement in writing and motivations for a course, and to provide scaffolding in prompts to facilitate more expressive and metacognitive writing. Giving students the opportunity to address what they know or do not know (metacognition) through reflective writing aided them in shaping their understanding of each scientific topic after their learning activities. Those who are engaged in this process were able to produce a quality product through their reflective essays. Therefore, our results revealed that students with mastery achievement goals bought into the purpose of our study but this does not apply to all students in this group. Regardless of the type of achievement goals students most identified with, they will still have underlying goals from both categories and this would explain the decline in engagement over the semester as students prioritized other courses and assignments. Therefore, this also revealed that achievement goals are not static throughout the semester and is a factor in how students complete their assignments and how they approach reflective writing.

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**Appendix**

*DLR and Reflective Essay Analysis with Model Student BIOT303-29*

After collection of data and analyses, BIOT303-29 was selected as a model student in the course who viewed the opportunity of metacognitive reflective writing as both a process and a product. BIOT303-29 was classified with mastery achievement goals and engaged in the metacognitive process through reflective writing and understood the importance of a 3D science approach to teaching. They were fully or mostly engaged in almost all of their DLR submissions and provided mostly target explanations in their reflective essays. The following text is the model student's DLR #4 submission (Learning Activity to Uncover K-5 Student Thinking) for the first DCI, **LS1-From Molecules to Organisms: Structures and Processes (LS1-DCI).** Text highlighted in green represents the claim and yellow represents the examples and evidence given in their reflection to elaborate on their prompt**:**

BIOT303-29, DLR #4 for LS1-DCI

- What's something new you learned today about how elementary school children make sense of **the structures and processes of living organisms**?

Something new that I learned yesterday about how elementary school children make sense of the structures and processes of living organisms was how narrow the view was across the grades. I was shocked by how little the older students knew and how much the younger kids knew and how both groups' thought processes seemed to center round the same couple of concepts. The kindergarten students were able to tell if something was alive or not, for the most part, by determining if it grew. I thought this was a great understanding of life for a kindergartener. The 1$^{st}$ and second graders also impressed me with their responses. Most seemed to have a good grasp of the structure and processes of plants. However, the 3$^{rd}$, 4$^{th}$, and 5$^{th}$ graders seemed to remain a bit shallow in their understanding of the structure and processes of living things. This is likely a trend across districts as many of us conducted our probes in various districts.

- What still puzzles you about how elementary school children make sense of **the structures and processes of living organisms**?

So, I guess the puzzle for me about how elementary school children make sense of the structures and processes of living organisms was kind of touched on in class as well as other DLR's. Why are so few examples and/or models used in elementary classrooms to help students understand the structures and processes of living organisms? Additionally, why are we just now implementing new standards and methods such as 3D learning. It seems like this should have been addresses decades ago. If a 5th grader's understanding of what a plant needs stops at sunlight and water, the educational system is failing our students. As a parent, I understand the importance of creating opportunities to expose children to learning experiences and broaden their horizons. Nevertheless, this is not always possible for many parents due to work or limited resources. It is incumbent upon us as teachers to provide as many models in the classroom as possible in order to provide better learning outcomes for our students.

BIOT303-29, Reflective Essay #3 for LS3-DCI

The following text is the model student's reflective essay submission for the third project, **LS3-Heredity: Inheritance and Variation of Traits (LS3-DCI).** Text highlighted in green represents the claim and yellow represents the examples and evidence given in their reflection to elaborate on their prompt**:**

*Prompt 1 -* BIOT303-29 made reference to *LS3.A: Inheritance of Traits* and *LS3.B: Variation of Traits,* the two sub-topics under LS3-DCI. Upon mentioning these two topics (claim – green), they explained the significance of each with examples to help facilitate understanding (evidence – yellow). BIOT303-29 also provided examples of how each one could be understood and taught to students in K-5. BIOT303-29's Prompt 1 is ideal and was classified as a target explanation.

> The disciplinary core ideas associated with the inheritance and variation of traits in organisms are explained through heredity. Offspring normally resemble but are not identical to their parents. Certain characteristics are passed on through genes from one generation to the next. These genes transmit specific information that create proteins that express those characteristics passed on from the parent organism. The passing on of genetic material for many organisms can be accomplished through sexual reproduction which allows for more variation between parent and offspring. LS3.A and LS3.B are designed to explain to explain the inheritance of traits from one generation to the next. They illustrate how DNA molecules make up the chromosomes that carry the genetic instructions for the characteristics that are being passed to the next generation and, in sexual reproduction, half of the genetic information comes from each parent and this is why a child will look similar to their parents but not identical. A child can have freckles and red hair while both parents are blond and fair skinned but both parents must have the red hair recessive gene in their DNA. Another example would be a son looking a lot like his father, but grows to be taller, have different color eyes, and need glasses. They are similar, but not identical.

*Prompt 2* - K-5 Student Sense-Making is the topic for this prompt and its particular DCI. The student was prompted to explain if the students they interviewed for this DCI were able to understand the material being presented to them through learning probes and activities and how they made sense of the topics posed to them. Not only did they elaborate on how the students made sense of inheritance and variance of traits, but they explained the disconnect between students' conception about heredity and what should be understood. Prompt 2 was classified as a target explanation.

> Based on what I have learned from our group's student interviews and the presentations that my classmates gave about their interviews, it seems to me that most elementary school children make sense of the inheritance and variation of traits in organisms through their own learned assets that they picked up from friends and family and personal experience. For example, in the baby mice probe, the majority of kindergarten through third grade students seemed to think that since the father mouse was black then all the males will be black and since the

> mom was white, all the females would be white. I think this is due to having too few standards for heredity in the earlier grades. However, by the fourth grade, it seemed that some formal science instruction was beginning to seep through. They were more aware of the differences and similarities and understood that half of genes come from the mom and half from the dad. Our fifth graders really knocked it out of the park. Most of the students we interviewed were able to make sense of how heredity affected eye color. They were able to describe how DNA is transferred from one generation to the next and how ancestry plays a major role in what traits are inherited by successive generations.

*Prompt 3* - Science and Engineering Practices (SEP) are emphasized as tools of inquiry when engaging in scientific investigation. This student shared a few of these practices such as Developing and Using a Model, Analyzing and Interpreting Data, and Planning and Carrying Out Investigations and connected these to specific examples. Prompt 3 was classified as a target explanation.

> The importance of scientific and engineering practices in helping elementary school children make sense of the inheritance and variation of traits in organisms is extremely important. Developing and using a model to help understand inheritance and variation in traits would be very useful. Students could use plants in the classroom to see which plants could go without water the longest or which plants grew tall fastest to optimize sunlight. They could then record, analyze, and interpret the data and decide which plants had the best traits for particular environments. Students should have opportunities to plan and carry out several different kinds of investigations during these early grades. In all grade levels, students should be given a chance to perform investigations that are designed by the teacher in order to expose an issue or question that they would be unlikely to explore on their own, like tracking the phases of the moon, to those that may arise from students' own questions and puzzles. Either way, these scientific and engineering practices are an integral part of the 3D learning process because they make learning concrete and tangible for students who may have a hard time with the abstract.

*Prompt 4* - With CC, students were connecting different domains of science through organizational structures to better interpret data and clarify material of the DCI. BIOT303-29 connected concepts in science with other CC in curriculum like English Language Arts and Math and how these CC were used in tandem by providing examples. Prompt 4 was classified as a target explanation.

> An example of a crosscutting concept that relates to 3D learning about the inheritance and variation of traits in organisms would be for English Language Arts. Integration of Knowledge and Ideas: CCSS.ELA-Literacy. RI.3.7. Use information gained from illustrations such as maps, photographs. This can be accomplished with a simple lesson like the probe for eye color. The student could infer from pictures of a family tree if it were possible for a particular couple to have a baby with blue eyes. Another example for crosscutting that relates to the 3D learning about inheritance is also related to the science and engineering practice I mentioned about the plant data collection.  Represent and interpret data. CCSS.Math.Content.3.MD.B.3 Students can draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs. For example, draw a bar graph in which each square in the bar graph might represent one inch of plant growth. Also, CCSS.Math.Content.3.MD.B.4. Students can generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units such as whole numbers, halves, or quarters. We just hit all 3D's in one activity!