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A Granular Account of Student's Understanding Reasoning within an Everyday and Scientific Contexts

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A GRAN ULAR ACCOUNT OF STUDENT'S UNDERSTANDING REASONING WITHIN AN EVERYDAY AND SCIENTIFIC CONTEXTS

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Teachers and educational researchers in the Maine Physical Sciences Partnership (Maine PSP) at the University of Maine identified making quality scientific arguments as a struggle for students. Not only is argumentation hard, but reasoning is the hardest component of an argument. Many frameworks have been developed to target teaching about argumentation but do not address how to teach one component of an argument in isolation. Educational practitioners encourage using everyday context to learn about arguments in the scientific context, but there is limited support in what is the best method.

The first purpose of this research was to understand a more granular account of students' understanding of reasoning's role in an argument. This purpose is addressed by analyzing transcriptions from interviews with students determining what the role of the critical feature in an argument was, in the case of this study, reasoning. Students cognitive output related to what they thought about reasonings role during a contrasting case activity was categorized based on natural separations in the data.

The second purpose of this research was to understand how students might connect reasoning in everyday and scientific contexts. This purpose was accomplished by providing opportunities for connection. Students application to and from both contexts was evaluated based on if they applied a consistent pattern of expression in their understanding.

The findings indicate that students can learn about one component of an argument when it is taught in isolation. In addition, students have a more detailed understanding of reasonings role than the current literature defines. In addition, students attempt to connect the everyday context with the scientific context. However, students either developed an understanding of reasoning in the everyday context and then faded in this understanding when using the scientific context, or the students made progress when attempting to connect the arguments. Further consideration of these aspects is needed when designing an activity to support students learning about reasoning in an argument. Teachers can use this data to inform how a task can be set up to deepen students' understanding of reasoning's role with relation to the connection to the evidence.

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CHAPTER 1

INTRODUCTION

With the current emphasis on educational standards in the science classroom, argumentation is important. Literature and practitioner resources have identified reasoning as the most challenging component of an argument to construct incorporate and shows the least amount of improvement after instruction (McNeill, Lizotte, Krajcik & Marx, 2006; Lizotte, Harris, McNeill, Marx & Krajcik, 2003; Sadler, 2004; Lizotte *et al.*, 2003, Bell & Linn, 2000; Robertshaw & Campbell, 2013; Yerrick, 2000; vanGelder, 2000; Berland & McNeill, 2010). The study presented here focuses on how students think about the role of the reasoning component with relation to how it connects to other components of an argument. Reasoning is defined as a connection between the claim and evidence; specifically, it provides the logic or justification for why the evidence is related to the claim (McNeill et al., 2006). McNeil et al. (2006) concluded that students can typically provide the claim and evidence portions of an argument but fail to properly link them with the scientific principles, that supports the connection. This leads to the question why reasoning is challenging for students to grasp.

Some studies recommend what the structures of an argument are (Toulmin, 1958; McNeill et al., 2006; Sampson, 2014) yet other studies recommend how to teach it (Erduran, Simon, & Osborne, 2004; Erduran, Ardac, & Yakmaci-Guzel, 2006; Hillocks, 2011; Nussabaun & Edwards, 2011). It is important for students to understand what the components of an argument are, while also recognizing the role of each component in an argument. It is especially important to clarify how reasoning functions in an argument, knowing that it is challenging for students to incorporate. The current studies present the reasoning component as a unitary entity. They do not break reasoning down into a finer description. If teachers want their students to be successful in making an intelligent and effective argument, then the teachers need resources that support them to teach reasoning. However, there is currently little understanding about how to effectively teach what reasoning is and its role in an argument. This thesis aims to provide insight from a more granular perspective on what students understand about the role of reasoning in an argument and how reasoning relates to other components of an argument.

In the present study, we recorded interviews with pairs of students who were asked to complete an activity using contrasting examples, with and without reasoning, to help them isolate the role reasoning had in sample arguments. Students' cognitive output was measured and analyzed using qualitative methods. Students' furthest understanding of reasoning was determined, and natural categories of understanding were established, creating a more granular account of what students can learn about reasoning. Variations and patterns between groups are reported on as well as different modes of discussion.

The findings of this study show that student understanding of reasoning varies, and we need to further investigate and highlight some of the substructures that reasoning contains. Some students identified reasoning as additional information that could play a significant role in an argument but did not know what the function level of this role was. Another variation was for students to notice that reasoning is related to the claim of the argument and understood that reasoning helps explain why the claim is true. The most advanced thinking students noticed that reasoning is related to multiple components of an argument. In this thesis, students noticed that reasoning can act on the other components separately or connect the other components.

CHAPTER 2

REVIEW OF LITERATURE

Scientific Argumentation

An argument is an assertion about a topic that provides justification in an attempt to establish truth (Kuhn, 1991; Osborne, 2010). Argumentation is the process of constructing verbal or written arguments (Duschl & Osborne, 2002; Osborne, 2010; Nassabaum & Edwards, 2011) and often relies on visuals such as graphs and models (Osborne, 2010). Arguments can be constructed to explain a scientific phenomenon or support an individual's opinion (McNeill et al., 2006). As Osborne (2010) puts it, argumentation is "the means that scientists use to make their case for new ideas."

Importance of Argumentation

Many researchers argue that argumentation should be a central component of science teaching, learning and incorporated into the science classroom discourse (Erduran et al., 2006; Erduran et al., 2004). Not only does it need to be a central component of the classroom but also needs to be included into the teacher's toolkit (Duschl & Osborne, 2002) in order for them to prioritize it (Driver, Newton & Osborne, 2000). Robertshaw and Campbell (2013) claim that science education needs to focus on making pre-service teachers' literate in argumentation in order for our youth to become literate too.

But why argumentation specifically? Studies have shown that argumentation enhances learning and aids in developing a more secure understanding of science in addition to knowledge construction (Robertshaw & Campbell, 2013; Berland & McNeill, 2010; Osborne, 2010; McNeill *et al*, 2006). Argumentation allows students to synthesize their current knowledge with the tentative knowledge they are encountering (Robertshaw & Campbell, 2013), which can diminish the gaps in their prior knowledge (Duschl & Osborne, 2002). Yerrick (2000) found that at the end of the argumentation unit, students included subject matter knowledge more frequently in the post interviews than they did before.

Not only does an understanding of the use and value of argumentation solidify students' knowledge but studies have also found that having a strong understanding of the content aids in using a higher level of thinking and abstraction when creating arguments (Aufschnaiter, Erduran, Osborne & Simon, 2008). McNeill et al. (2006) found that there was a positive correlation between students' multiple-choice scores in the content area and their explanation (argument) scores. Aufschnaiter et al. (2008) found that students' warrants (reasoning) were more developed when students included a more concrete knowledge or (rarely) with a reference to a scientific theory that constituted the connection between the data and the claim. It is important to note that understanding the content is not enough; students also need to understand the components of an argument (McNeill et al, 2006). Even though including the scientific context is important, it is not well understood how students can obtain an understanding in the everyday context and then make connections to the scientific context.

Encouraged through National Standards (NGSS)

National standards highly influence the curriculum taught in schools with teachers and educational researchers always seeking ways to better support students and meet those standards. Many of the more recent national standards require the use of scientific argumentation;

specifically knowing the components of an argument and how they function with the intent that students will create arguments that are efficient and logical to convince an opponent. The *Next Generation Science Standards* (NGSS Lead States, 2013), the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993), the *Common Core State Standards* (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010), the *National Science Education Standards* (National Research Council, 1996), and the *Inquiry and the National Science Education Standards* (National Research Council, 2000), are some of the most notable national standards that encourage students to gain a proficiency in argumentation. The difficult part is that many of these frameworks do not provide information about how to effectively teach the components of an argument or how the components of an argument are related to one another. The present study seeks to expand our knowledge of how students understand the relationship between reasoning and the other components of argumentation, as well as how students connect, reasoning within the scientific and the everyday context.

NGSS, under the National Research Council, published the document, *A Framework for K-12 Science Education* (2012), which identified several standards that students should become proficient in before graduation. NGSS recognizes that reasoning is a particularly difficult part of an argument to create and as a result has made it a prominent part of the framework. Specifically, the framework is separated into three integral components: scientific and engineering practices, disciplinary core ideas (DCIs) and crosscutting concepts. The DCIs include the core knowledge students are expected to become proficient in and provide a foundation for future learning. As a student progresses, the depth and sophistication of concepts also increases. The crosscutting concepts include the similarities between the different avenues of science. The scientific and engineering practices are the ways in which scientists engage in scientific investigations. These practices help students understand how scientific knowledge develops (NRC Framework, 2012). Eight core practices have been isolated (Table 1); argumentation falls within practice 7: Engage in argument from evidence. In this practice, students are expected to use reasoning to justify a claim, similarly to how scientists do in both the formal (peer review or conferences) and informal (lab meetings) settings (NRC Framework, 2012). This practice expects students to be able to use reasoning but does not provide any guidance for the teachers on how to introduce this concept or how reasoning is related to other components taught.

Table 1

Science and Engineering Practices from the NGSS

1) Asking questions (for science) and defining problems (for engineering)
2) Developing and Using Models
3) Planning and Carrying out an Investigation
4) Analyzing and Interpreting Data
5) Using mathematics and computational thinking
6) Constructing explanations (for science) and designing solutions (for engineering)
7) Engaging in argument from evidence
8) Obtaining, evaluating, and communicating information

Major Frameworks for Teaching Argumentation

Due to the difficulty and uncertainty of why argumentation is hard, many researchers and practitioners have created frameworks to support students' argumentation development skills.

For the intensive purpose of this study, an explanation of three major frameworks that teach argumentation will be discussed with emphasis on their focus towards the reasoning component.

Toulmin's Argument Pattern (TAP)

Most commonly cited and implemented is TAP (Toulmin, 1958). The structures of an argument under the Toulmin framework include: a *claim; data* that support that claim; *warrants* that provide a link between the data and the claim; *backings* that strengthen the warrants by providing a premise (Osborne, 2010); *rebuttals* which point to the circumstances under which the claim would not hold true (Erduran et al, 2004) and *qualifiers* that address the limits of the claim (Osborne, 2010). Toulmin lays out what the middle of an argument should include. Within the present study, the backing and warrants of Toulmin's framework are combined to form the reasoning component of an argument.

Claim, Evidence, Reasoning (CER)

McNeill et al. (2006) established another framework to teach argumentation, which adapted Toulmin's Argument Pattern by simplifying and combining terms that students could not understand easily as well as help align argumentation with the national standards. The structure of an argument in McNeill's framework include stating a claim, supported by evidence and connected through reasoning, often referred to as Claim, Evidence, Reasoning (CER). A claim is defined as "an assertion or conclusion that answers the original question." Evidence is defined as "scientific data that supports the claim." The evidence needs to be appropriate (relevant) and sufficient (adequate amount). Reasoning is defined as "a justification that shows why the data count as evidence to support the claim." The CER framework is more student friendly because it reduced the complexity of TAP and focused the learner's attention "on relevant features"

(McNeill, 2006). Reasoning is also the term used in the standards, which makes it more familiar to teachers and students.

Argument Driven Inquiry (ADI)

Another major example of a pedagogical strategy used to teach argumentation is ADI (Sampson, 2014). This approach uses student-centered learning experiences that addressing NGSS practices and disciplinary core ideas. ADI provides students with the opportunities to explore why things happen while they figure out how they work. Students are asked a specific guiding question, or required to develop a solution to a problem, similarly to how real science is done. Not only do students focus on the NGSS standards, but the ADI website emphasis that students are also learning "how to read, write, speak and listen in science because it makes scientific argumentation the foundation of all laboratory activities." Argumentation is an integral part of this framework, throughout the eight stages of the learning activity, students are performing experiments, collecting data, writing arguments, critiquing theirs and their peers, and making revision. The ADI framework uses a similar approach to an argument as the CER, however they do not refer to it as reasoning. They refer to reasoning as a justification of the evidence and define it as *"a statement that explains the importance of the evidence by making the concepts or assumptions underlying the analysis and interpretations explicit"* (Sampson, 2014).

The TAP, CER and ADI frameworks support students understanding the scientific discourse that scientist as well as people in the community use to effectively argue their point. Other researchers have either adapted these frameworks or tried other methods to promote argumentation, discussed later.

Reasoning

Reasoning is defined in a variety of ways by the literature, with much of the consensus focusing on reasoning being a connection between the claim and the evidence; specifically, it provides the logic or justification for why the evidence is related to the claim. Reasoning is often associated with scientific principles. However, students less frequently include the scientific principles in their arguments (McNeill et al., 2006).

Reasoning has been highlighted as the most challenging component of an argument to incorporate at a high quality and shows the least amount of improvement after instruction (McNeill et al., 2006; Lizotte et al., 2003; Sadler, 2004; Bell & Linn, 2000; Robertshaw & Campbell, 2013; Yerrick, 2000; vanGelder, 2000; Berland & McNeill, 2010). McNeill et al. (2006) found that regardless of treatment group, the reasoning scores were the lowest. Students were more likely to provide evidence than reasoning. In a definitional manner this would make sense because the definition of reasoning is to provide the connection between the claim and the evidence, so first students need to make realistic claims with adequate evidence before they can provide appropriate reasoning (Berland & McNeill, 2010). This leads into a possible reason behind why reasoning is so challenging for students to grasp. Perhaps students do not share a common definition or do not understand the way we define reasoning for them (McNeill et al., 2006).

Another reason students struggle with reasoning could be due to insufficient content knowledge (Aufchnaiter et al., 2008; Osborne, 2010; McNeill et al., 2006; Erduran et al., 2004). They have a lack of knowledge of the content and it is not a lack of reasoning capability. McNeill et al. (2006) found that students, who scored high on the multiple-choice content exam, also had higher scores on their explanations (arguments) for that content area. However, having context knowledge does not imply that you will be successful at argumentation, you must also be proficient in the components of an argument and how they function.

Since "science education has placed its emphasis on *what* should be believed in rather than *why* something should be believed in (Erduran et al., 2006)" providing reasoning in an argument is not a simple task. For students' mindsets are programed to take in knowledge rather than integrate the knowledge to explain why something is true. This approach to learning does not promote looking at science from a scientific inquiry method where questioning and reasoning are emphasized, therefore making reasoning a difficult task for students. However, many researchers and practitioners have sought to change this mindset and help students develop quality arguments.

How has reasoning previously been taught?

Research on argumentation and how to develop students' skills is still in its infancy (Osborne, 2010), but many researchers have made attempts to support students developing stronger scientific arguments. As mentioned before, three of the most common frameworks to teach argumentation are Toulmin's Argument Pattern, the Claim, Evidence, Reasoning framework and the ADI framework. However, many other researchers have modified these two or designed their own. The following describes a sample of variations.

CER. The Claim, Evidence, Reasoning (CER) framework, has been implemented many of times in a variety of ways. The most common application of the framework is through scaffolding the structure. Initially the students are provided the term and the definition, and then the definition is removed. For instance, in McNeill at al's (2006) study, students were separated into two treatment groups, treatment 1 received the term and the definition. The scaffold says "Reasoning (In your reasoning statement, connect your claim and evidence to show how your data links to your claim. Also, tell why your data count as evidence to support your claim by using scientific principles. Remember reasoning is the process where you apply your science knowledge to solve a problem.).” In treatment 2, the students received the definition in the form of a probing question in the context of the situation, their scaffold says, “Tell why properties being the same or different tells you whether two stones are the same substance.” To aid the students in formulating a stronger argument, the teacher used various “instructional strategies such as defining scientific explanation, modeling how to complete the practice, and providing students with feedback (McNeill et al., 2006).” On the post-test students in the context specific group with the content specific scaffold scored higher on all structural component of an argument, even reasoning. The science knowledge of treatment 2 was also higher on post-test scores. From this method of instruction, the students are specifically learning reasoning’s definition from the scaffolding on the worksheet. As McNeill et al., states “decreasing the amount of detail can be particularly important for the general support since the students eventually internalize the framework and the definitions of the components.” So, from being supplied with the definition in the scaffold and repeated practice, students are expected to learn what the definition is. With respect to reasonings importance their only chance to gain insight to what this might be is because the scaffold tells students to include it. However, McNeill et al’s (2006) study did not focus on what students learned about reasoning, just that they could include it on post-tests. With disappointment, the students did not learn reasoning’s function, or the consequence when reasoning is not included in an argument.

Reason! Software. In 1999, van Gelder evaluated the quality practice hypothesis and the strong situated hypothesis and found that:

"…the best way to have people engage in quality practice is to have them coached individually or in small groups by human experts."

With individual coaching in mind, The Reason! Software was created because it is difficult to have an expert work one-on-one with a student. Reason! introduces students to the fundamentals of informal reasoning and provides them with an environment for quality practice of emerging reasoning skills. In the Reason! Software students create an argument tree, which is a graphical representation of the parts of an argument. The student also learns how these parts fit together, which aids the student in scaffolding their arguments. After the argument tree is created, the student comes up with an evaluation judgment, which is like McNeill's claim. Following this claim the student is asked to decide if the premise they made is true. Similarly, to McNeill, through probing questions, the student creates an argument with all the parts, but vanGelder (1999) does not address what the students understand about the role of reasoning.

Co-Construction. Another way that reasoning is being taught is through teacher modeling using a co-construction framework. Erduran et al. (2004), used TAP to support students in learning how to reason through practice and teacher modeling. Since warrants and backing are hard for students, the teacher frequently provided the warrants and backing in a co-construction formation of an argument. Erduran et al. (2004) proposed that if the teacher initially is providing the warrants and backing, eventually, as the students get more confident and see this form of modeling, the students will begin to provide their own warrants and backing. However, just like the CER framework, students may be taught about the structure, but in this format, it is still unclear what students understood about the roles of these terms. In a later study, Erduran et al. (2006) used discussions to teach reasoning. Students were asked to present an argument for and against funding zoos. Through discussions of the pros and cons of a situation, reasoning was learned. During the activity students took a stance and provided their evidence. In the discussion, the teacher initially produced the warrant (component of reasoning) for the student but later in the activity, the students began providing warrants from hearing how the teacher modeled this aspect of arguments. The term reasoning was not explicitly taught but was learned through practice and teacher modeling. Again, it is unclear what students learned about reasoning other than the encouragement to include it. In the literature, this is an example of a time where an everyday context is used, however, it does not focus on how to or what was transferred back to the scientific context.

Whodunit Mysteries. Another instance which used the everyday context to learn about reasoning is through whodunit mysteries (Hillocks, 2011). In these mysteries, students are shown a crime scene and asked to decide how the victim dies. The teacher provides prompting questions and the students start with providing evidence from the scene. Once they have enough evidence, they can make a claim about how the person could have died. To come up with support (evidence) for their argument, the students hold group discussions. Afterwards, the students are prompted to create a rule for each evidence statement by explaining "how each piece of evidence supports your claim." This is where the students learn about reasoning, even though it is not explicitly referred to as reasoning. The Whodunit mysteries framework are similar to CER, but Hillocks orders the components differently and emphasizes highlighting your evidence first, then making a claim, supported by a rule (reasoning), ending with a conclusion. Consistently with the other studies, students learn a structure of an argument, but it is still unclear how the student is expected to learn the role of reasoning and the consequence for not including it.

Similarities in Teaching Reasoning. All these approaches provide students with a structure for an argument. Whether explicitly referring to it as reasoning or through other means, these studies emphasize that reasoning should be included in an argument but there is a lack of understanding around how to teach the role of reasoning with respect to its relationship to other components within an argument. However, many functions of reasoning are left unanswered, such as what is the role of reasoning in an argument and how it is related to other components, or how is the argument affected when reasoning is not present, or what is the contrast between reasoning within everyday context compared to scientific context.

Given the existing literature just defined, there is a gap to understanding what students can learn about reasoning's role in an argument, its effect when it is not present and how the science context can be learned from everyday examples. Therefore, I set to investigate how students think about reasoning's role with the use of contrasts.

Deficiency in Literature

With respect to current literature and practitioner resources for teachers, I have three areas of focus for this study where the literature is lacking. First, there is a lack of information about how reasoning might be made a special focus of instruction. Secondly, there is a lack of information, especially in the practitioner resources, about how students can generate their own definition of reasoning during instruction and perhaps most relevant to this thesis, to what extent this definition will be connected to the other components of an argument. And finally, there is a lack of information about how students connect everyday and scientific contexts.

Regarding practitioner resources, there is a lack of knowledge about how reasoning can be made a special focus of instruction. Reasoning is often taught in conjunction with other components. McNeill and Krajcik's (2012) book series offer strategies for how the CER framework can be introduced and integrated into the classroom instruction. These ways include but are not limited to: (1) discuss the framework, this would be the students introduction to the components and their definitions, (2) connect to everyday examples, the goal would be to use the framework in the context of what students can relate to, (3) provide a rationale, this would include showing and telling students why the components and an argument as a whole are important, (4) connect to other context, similarly to the everyday connections, it is important to use the framework in other subject areas to show students its versatility, (5) provide students with feedback, which allows them to make their arguments better, and the last few strategies are related to examining other arguments (6) model and critique examples, (7) have students engage in peer critique as well as (8) debate student examples, all of which allow students to examine examples that are stronger and weaker than their own. A commonality among all these strategies is that students are not learning one component in isolation, they are focusing on the argument as a whole. Possibly when a component is missing from a critique, students could infer that something is lacking, but this is the closest, other than the initial teaching, when they discuss the definition of each. Not much attention is directed towards how the components are related. Often in these strategies students come to an understanding of reasoning through argument practice. Another example of a practitioner resource that does not make a particular component of an argument a special focus in their instruction is in the ADI framework (Sampson, 2014). Often reasoning is learned through argument practice after an investigation with subsequent critiques and reflection from the teacher and peers. Another instance of where instruction does not make reasoning a specific focus is the Whodunit mysteries. Within this instruction, reasoning is practiced after students make observations of a mystery scenario. When practicing reasoning, students are asked to think of a rule to try and make sense of those observations. Students are implicitly learning that reasoning clarifies the evidence, but reasoning’s role is not the special focus of instruction as it is still taught in conjunction with the other components. A common theme among these frameworks is that reasoning is best learned through practice and in conjunction with other components of an argument. Not understood well is how an understanding of reasoning can be gained with a task where reasoning is isolated from practicing the other components.

Even though reasoning is the hardest element of an argument (McNeill et al., 2006; Lizotte et al., 2003; Sadler, 2004; Bell & Linn, 2000; Robertshaw & Campbell, 2013; Yerrick, 2000; vanGelder, 2000; Berland & McNeill, 2010), practitioner resources frequently predisposed students to a less granular definition of reasoning that the researcher or teacher wants the student to gain. McNeill and Krajcik's (2012) book series encourage teachers to take a day to introduce the framework. During this instruction, usually as a class, students generate a definition of each component. Depending on how the teacher introduces these components, there is opportunity for illustrating how reasoning is important. However, during this generation of definitions, the teacher is shaping what the final definition of each component should contain and it is frequently created from a compilation of student's responses. Often the definition generated established reasoning as a unitary entity. Although this is a complex process, it usually includes the whole class and therefore does not always allow each student to participate in this construction task. In studies using the CER framework, the definition of each component of an argument are often included in scaffolds. As time progress the scaffolds become vaguer to the point that they are removed. In this instance, removing the scaffold makes the students internalize the definitions. McNeill and Krajcik (2012) state that "decreasing the amount of detail can be particularly important for the general support, since the students eventually internalize the framework and the definitions of the components." Similarly, the ADI framework (Sampson, 2014) introduces a definition of reasoning that they want students to use. Again, the definition students are provided with does not target all of reasoning's functions. Reasoning skills are gained from practicing the provided definition, peer critique and teacher feedback, as well as being able to revise their work. Overall, these frameworks do not put much emphasis on students constructing a more granular working definition of reasoning as a special focus of the lesson. A question of concern remains, how do students generate a more precise understanding of reasoning's role and will this understanding encompass all the focus the literature and practitioner definitions entail?

Practitioner literature encourages a connection of argumentation with the everyday context, however in many of the cases where the everyday context has been used, the focus on reasoning is minor in terms of the overall goal. For instance, in the book series from McNeill and Krajcik (2012) the everyday examples provided from classroom scenarios often focus on other components of an argument. One specific instance (pp 74) was a teacher who used claiming a certain music band was the best ever; in this situation the class ended up focusing on evaluating if the evidence was relevant and whether the data was indeed evidence or opinions. McNeill and Krajcik (2012) encourages teachers to "discuss the similarities and differences between using the framework in everyday examples as compared to using them in science" and recommends questions that can be asked to prompt discussion. Another method of instruction is the Whodunit mysteries. These target everyday examples without explicitly referring to them as such. However, in these resources Hillocks does not reference how the knowledge students gain about the components of an argument can be transferred to the scientific context. Notice how in each of these practitioner resources, what students can generate as an understanding of reasoning's role from the everyday context is still not understood well. McNeill and Krajcik (2012) references that discussing similarities and differences from the everyday compared to the scientific is important to do, but only provides some discussion prompts to do this. For these reasons, the practitioner resources are lacking in information about how to connect the everyday and scientific contexts to help students generate stronger scientific arguments.

Much of the literature does not focus on what the need for the reasoning is. There is not a focus on if the argument has an obvious need for reasoning or if the need is subtle. The closest the literature or practitioner resources come is through one of the recommendations McNeill and Krajcik (2012) offers. In this instance, everyday examples are used to be evaluated or critiqued. In these situations, the examples are frequently weak in nature and most of the observations about reasoning are surficial, mainly only mentioning that reasoning is missing. Therefore, the practitioner resources are lacking in information about what degree the need of reasoning should be, and how this need can be used within a scientific or everyday context.

Purpose

Given the need for knowledge about how students can understand reasoning when it is a special focus of instruction just as described earlier, the present study has two purposes. The first purpose is to present a more granular account of how students may think about reasoning than is currently available in the literature, and secondly to gain insight into how students may connect the everyday and scientific contexts. To accomplish these purposes, this study presented students with arguments in the subtle scientific context and the more obvious everyday context. These arguments were arranged using contrasting cases (Schwartz, Chase, Oppezzo, & Chin, 2011) to highlight the reasoning component of the argument when synthesizing a general explanation (Shemwell, Chase, & Schwartz, 2015), which has been shown to support students developing an understanding of a specific concept. The analysis of the results determined a more granular account of how students understand reasoning's role in an argument and students will attempt to connect the everyday context with the scientific context. However, students either developed an understanding of reasoning in the everyday context and then faded in this understanding when using the scientific context, or the students made progress when attempting to connect the arguments. Overall, the results of this study indicate that students can generate an understanding of reasoning to varying degrees when it is a special focus of instruction. The new insight from this study informs the use of isolating a component of an argument to learn about its role and informs how different contexts can be used to enrich learning about reasoning.

CHAPTER 3

METHODS

Design

To determine a more granular account of how students think about reasoning I chose to perform an intense study of student pairs to analyze their cognitive output of what they thought about reasoning's role. This approach makes student thinking more explicit and allows for a closer analysis into student thinking. Since the process for learning about what students understood was not yet known, I measured their cognitive output. To meet these design requirements, students were grouped in pairs to promote discussion. Students were presented with arguments in contrasts. An additional design feature included two question series; the first question directed students to focus on reasoning's role when it is present in an argument and the second question directed students to focus on what happens when reasoning is absent from an argument.

To understand how students might connect the everyday context with the scientific context I set up a learning experience that provided opportunities for connection. To meet these design requirements, I used a contrast matrix to facilitate close comparisons between arguments within the everyday context and those within the scientific context, these will be discussed in more detail later in this section.

Research Questions

This study was designed to answer two main research questions:

Research Q1: What did students think about the role of reasoning?

Research Q2: How far did students' thinking progress with the scientific context arguments compared to the everyday arguments?

Context

This study took place at a public middle school located in a small rural town in central Maine that was representative of surrounding towns in the area. The teacher was part of the Maine Physical Science Partnership (PSP) and taught *The Science Education for Public Understanding Program (SEPUP) Issues in Earth Science* curriculum. The proportion of male-female students was 11 and 9 respectively, with one female- female pairs, seven female -male pairs and two male – male pairs.

Participants

Twenty, sixth grade students worked in pairs on the activity, creating a total of ten groups. This small sample size is due to the volunteer nature of the study's recruitment and based on those who returned a completed parental guardian permission form. Middle school students were selected because at this point in their science career they are beginning to make scientific arguments in their curriculums. Most of the students were white and non-Hispanic.

Recruitment and Assignment

To recruit students, they were asked to volunteer for the study. All the students who returned their signed permission slips were included in this study. The articulacy level of the students was the primary consideration and a substantial focus was centered on whether the students could work effectively together; so, the teacher established the pairs of students. Using pairs of students increased the amount of discussion, which provided evidence about what the students were thinking.

Procedure

In each interview the learning task was audio-recorded with the pair of students and a researcher. The audio device was positioned between the students and the researcher informed the students that they were being recorded for the study. During the task, the students were informed to speak out loud and again reminded throughout when needed. Since there were two researchers, myself included, a script (Appendix A) was used to keep the interviews consistent. When the pair of students agreed on an answer, they would document this answer down on the activity sheet, occasionally needing prompting to do so. If the student provides a quick direct response to the questions on the activity sheet, the researcher would encourage students to elaborate on their answers. When it appeared that a student was done with one aspect of the activity, they would be asked if they were ready to move on. At this time, the sheet they were currently working on was collected and the new sheet was administered. The activity had four major aspects: 1) pre and post assessment items, 2) warm-ups 3) the major focus of this thesis, the contrast matrix activity, and 4) lastly, the teaching experience. A detailed description of the contrast matrix activity will be reviewed first and then a brief overview of the surrounding materials will be discussed.

Instructional Materials

Surrounding Instruction

An activity packet was developed to find a way that best evaluated learning and supported students understanding reasoning in a scientific argument. The packet was designed, modified and validated. The final activity packet (Appendix B), which was used for this thesis, contained: 1) pre-assessment, 2) warm-up A, 3) warm-up B, 4) contrast matrix, 5) teaching experience 6) post- assessment 7) reasoning effect, 8) sample argument. This thesis only analyzed student's discussion from the contrast matrix portion.

The Contrast Matrix

The contrast matrix (Figure 1) was the focus of the protocol. It was designed to help students generate an understanding about the role of reasoning in an argument.

In the Table below, Jamie's arguments have an extra sentence, starting with "importantly."

1. Compare Jamie's and Pat's arguments. Make a single overall explanation for how the "importantly" sentence make Jamie's arguments more convincing than Pat's arguments.

____

Pat's	Jamie's
• I know the mineral is diamond. • My evidence is none of the other minerals are able to scratch it.	• I know the mineral is diamond. • My evidence is none of the other minerals are able to scratch it. • Importantly, diamond is the hardest known mineral, so other minerals don't scratch it.
• I think I am going to get sick. • My evidence is I ate a granola bar with peanuts in it.	• I think I am going to get sick. • My evidence is I ate a granola bar with peanuts in it. • Importantly, I am allergic to peanuts.

Ask for another row if you would like another example

• We should not build the house on the hillside. • My evidence is the hillside is made of loose materials.	• We should not build the house on the hillside. • My evidence is the hillside is made of loose materials. • Importantly, loose materials can erode, so the house might fall.
• Becky, our class' ball python, is probably not hungry. • My evidence is she ate three weeks ago.	• Becky, our class' ball python, is probably not hungry. • My evidence is she ate three weeks ago. • Importantly, we know ball pythons typically go months without eating.

2. Leaving off the importantly statement makes Pat's arguments not as convincing as they should be. Why?

Figure 1 - Contrast Matrix Activity

When the students initially saw the contrast matrix it was set up as a 2 x 2 matrix, as portrayed in Figure 1 with the full dark lines. Each cell in the matrix is an argument. The argument's structure comes from McNeill and Krajcik's CER framework (2006). The arguments are bulleted and used a consistent expression for ease in recognizing each component -- the claim ("I think..."), the evidence ("My evidence is..."), and the reasoning ("Importantly..."). Figure 2 represents the design the contrast matrix. The matrix is set up into columns and rows to create a contrasting case scenario (Schwartz et al., 2011). Within a column, the argument pairs were set up based on their inclusion of the essence. Essence is the common dimension of interest (Shemwell *et al*, 2015), in this study, the reasoning. To easily reference the rows, fictitious gender-neutral names of Pat and Jamie were selected for students to relate to. The arguments in the right column - Jamie's - are the only ones which include reasoning. The rows are set up based on a gradation in salience. Salience is the degree of prominence, in this study, the ease of recognizing the critical feature or essence. In this study, the salience alternates, meaning that in the first argument with a low salience, the essence is harder and subtler to notice, compared to the next row with a higher salience where the essence is easier and more obvious to notice. The reason for starting with a low salient argument was to prompt a productive struggle amongst the students, then followed by a more obvious example. When students asked for more rows during the protocol, the arguments the students received continued to follow the pattern of subtle, obvious.

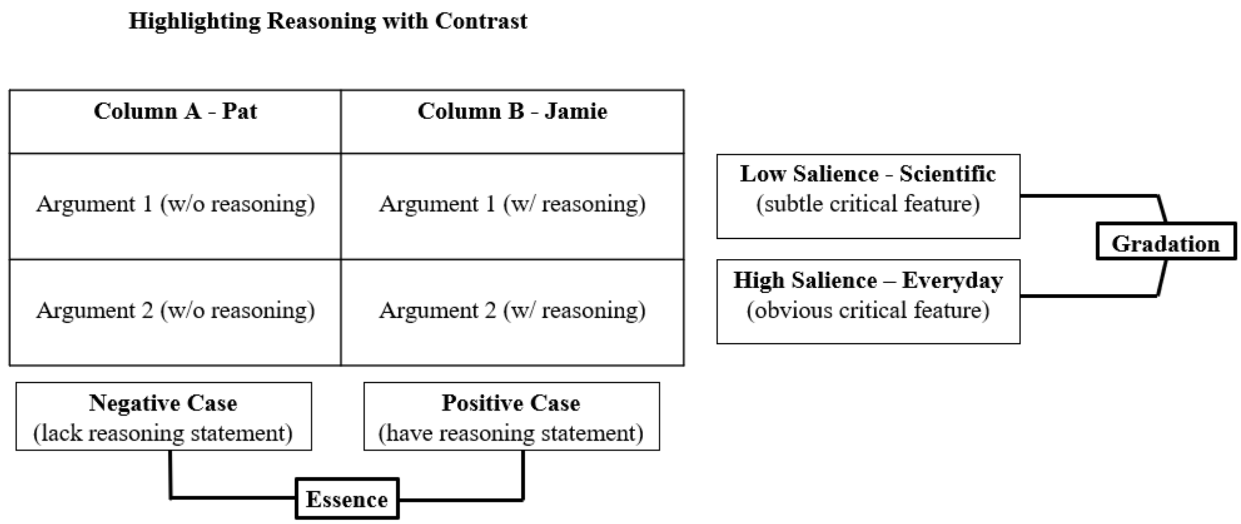


Figure 2 - Framework of the Contrast Matrix

The example arguments were designed from either typical student experiences - referred to as everyday arguments or from prior knowledge from the rocks, minerals, and erosion units of their sixth grade SEPUP curriculum - referred to as scientific arguments. It is important to note that the everyday arguments were significantly more salient than the scientific, meaning that the role of reasoning is more obvious to the students as compared to the subtle role of reasoning in the scientific examples. For this reason, when referring to the everyday and scientific arguments, they will be denoted as obvious everyday and subtle scientific, respectively.

In the learning activity, there were two prompting questions. The first prompt, (Figure 1), ask students to “Compare Pat and Jamie's arguments. Make a single overall explanation for how the importantly sentence makes Jamie's arguments more convincing than Pat's arguments.” This prompt focuses on the essence, reasoning. As the students answered the question, they were expected to construct a generalization statement related to reasoning’s role by contrasting one column with another. In between prompts, the students received an additional row(s), which was meant for them to self-evaluate if they really found an overall explanation or not (dashed lines of Figure 1). When they were satisfied with the additional row(s), the students moved onto prompt two, “Leaving off the importantly statement makes Pat's arguments not as convincing as they should be. Why?” Students were asked to focus on why Pat’s argument, which lacks the essence, is not as convincing. By drawing students’ attention to the deficiency, it is leading them to move past a surficial acknowledgement that something is missing and generate an understanding of reasoning when it is absent from an argument.

Sources of Data

The sources of data collected are: 1) audio recordings of students’ responses; 2) students’ written answers to the activity packet. The written answers were not used for this study, because they were not fully indicative of students thinking, instead this study relied solely on audio recordings and transcriptions created from the audio, which provided insight into student thinking.

Data Analysis

Data Representation

The overall approach was to code the data using qualitative techniques. From these codes, summaries were generated. The summaries were used to generalize what students were thinking about reasoning’s functional role. The four major data representations used for the analysis were (1) transcriptions, (2) process coding: line-by-line coded (Charmaz, 2002) (3) Narrative Summaries and (4) two variations of interpretations: (a) general interpretation, and (b) argument specific interpretations.

Transcriptions. The ten interviews were transcribed by section of the activity packet and put into an excel spreadsheet for easy access. The transcriptions were used for all future analysis to analyze the students processing of the activity packet, specifically the contrast matrix.

Process Coding. The first aspect of the analysis was process coding (Bogdan & Biklen, 2007; Charmaz, 2002, 2008; Corbin & Strauss, 2015; Strauss & Corbin, 1998) the transcription. I used line-by-line coding to become familiar with the data and conceptualize what students were understanding about the role of reasoning. To do this I read one line at a time and designated an -ing verb (Charmaz, 2002) to describe what the students understood at that instance, an example is in Figure 4 below. Each line-by-line code of the transcription was also color-coded light and dark based if it was contextual or abstracted, respectively. This color scheme allowed for an initial visual of how students were expressing their understanding of reasoning. The goal of line by line coding was to generate summaries that were as complete and unbiased as possible, for they would help define future analysis.

Table 2

Example of Line-By-Line Process Coding

Transcription	**Line-By-Line Process Coding**
Like he or she gives like a fact about the things, and he just says no other mineral are able to scratch it like we don't even really know what he's talking about. Like he acts, she or he umm says importantly diamonds are the hardest known mineral and so then you know what he's talking about in the sentence. GG: In which sentence? I mean this bullet	-saying that Jamie gives a fact -referencing the evidence sentence -noticing that you do not know what he's talking about (in the evidence sentence) -references the reasoning sentence -saying that by giving the reasoning sentence, the reader will know what you are talking about in the evidence sentence Interviewer Prompt: In which sentence?

Table 2. Continued

my evidence is that ... and then down here he just said I think I'm going to get sick, my evidence is I ate a granola bar with peanuts in it. we don't know why he's gunna get sick and then Jamie said importantly I'm allergic to peanuts, so that's why we know he is sick or going to get sick.	-clarifying that it is the evidence sentence they were referencing. -reading Pat's first two bullets (claim and evidence) -pointing out that you don't know why Pat's going to get sick but in Jamie's we do because he says the reasoning (importantly…)

<u>Developing Narrative Summaries.</u> The next process was twofold; each transcript was summarized into a narrative and then a general interpretation was created based on the main point of the narrative. To create the narrative, the line-by-line code was transformed into sentences relating to what the students were understanding about reasonings role while they processed the contrast matrix (table 3; left). The purpose of the narrative summary was to represent each group's processing and understanding as accurately, clearly, and concisely as possible to facilitate my further analysis.

<u>General Interpretation.</u> The second portion of this twofold summary analysis (table 3; right) compared the transcriptions and the narrative summaries to create a general interpretation about the students' furthest understanding. During the students' discussion about the arguments in the matrix, they referenced multiple arguments, expressed their understandings in a variety of ways, and provided fragmented thoughts. This made it difficult at times to accurately code what students understood about reasoning. Therefore, the purpose of this analysis was to have a representable interpretation of each group to be used to compare and determine a more granular account of what a student could understand about the role of reasoning. To create the general interpretation, the furthest understanding a student reached, relating to the definition of reasoning, was documented.

Table 3

Examples of a Narrative Summary and the Subsequent General Interpretation

Narrative Summary	General Interpretation
The students understand that the importantly statement gets the reader's attention. They also realize that it tells the reader why Jamie made the claim he did. For all of Jamie's arguments (PB and diamond) they say that the importantly sentence explains why the evidence is appropriate and valid. They discuss the importantly sentence, the evidence and the claim, and realize that the importantly sentence helps connect all the parts of the argument. They notice that the importantly sentence helps the reader realize why the evidence matters. Further, they notice that the importantly sentence provides additional information about situation to explain why the claim is stated. Finally, they say that the importantly sentence is extra information to support the evidence by proving the evidence is right.	Overall, the students understand that the importantly sentence connects to the evidence and the claim separately. And that reasoning explains why each is true.

<u>Specific Argument Interpretations.</u> Using the same process as used for the general interpretations, interpretations specific to each argument were created and compiled (Table 4) to compare how students were making connections between the everyday context and the scientific.

Table 4

Example of Specific Argument Interpretations

	Subtle Scientific - Diamond	Obvious Everyday - Peanut Butter	Subtle scientific - House on the Hillside
Student Transcript	*"says importantly diamonds are the hardest known mineral and so then you know what he's talking about in the sentence. GG: in which sentence? I mean this bullet my evidence is that."*	*"then down here he just said I think I'm going to get sick, my evidence is I ate a granola bar with peanuts in it. we don't know why he's gunna get sick and then Jamie said importantly I'm allergic to peanuts, so that's why we know he is sick or going to get sick."*	*"but they still get the detail that we shouldn't build it on that it's on loose material. R: yea, this just says why, he's just saying- he's not really explaining it."*
Specific Argument Interpretation	Provides insight into another sentence [evidence]	Explains why the claim is true	Additional information (more detail) to say why but not explain

To ensure that the narrative summaries and general interpretations were accurate for each individual group, careful consideration to continually reference the original transcript was used to maintain continuity between the different levels of data representation.

Process of Data Analysis

Analysis Framework

As previously stated, the purpose of this thesis was to determine a more granular account of how students may think about reasoning and to gain a better understanding of how students made connections between the everyday and scientific contexts. To achieve this goal, the analysis of the data most broadly encompasses determining the student's degrees of understanding reasoning's role. Some areas of focus' (Table 5) were A) how do student's expression vary when using a contextual manner compared to an abstracted one, B) how does the salience in the arguments affect students understanding, and C) how does the essence support student understanding. All analysis that compared understandings were based on the student's furthest understanding of reasoning's role within that mode.

Table 5

Various Modes in the Degree of Understanding Reasoning's Role

A) Expression	**B) Salience**	**C) Essence**
Contextual	Subtle Scientific	Absent Case
Abstracted	Obvious Everyday	Present Case

Identification of Categories of Understanding

To determine a more granular account of students understanding of reasoning's role all the general interpretations were compared side by side. The understandings were then ordered into a hierarchy to detect any patterns. It became evident that there were some natural separations based on distinct differences between groups. These separations are referred to as categories; descriptions and titles of the categories are based on the similarities of the group's understandings within that separation. Then, in a process of further refinement, each group was carefully evaluated as to whether it "fit" the category as described; meanwhile adjusting both the descriptions and which pairs belonged into which category. All the while maintaining a steady link back to the original transcript. Within these categories, students used different modes of discussing their understanding. These various modes and how they were analyzed are discussed next.

Expression: Contextual and Abstracted Expression

Initially during the line-by-line coding, and again while comparing the general interpretations within each category, other distinctions arose. One distinction was that students expressed their understanding of reasoning's role in a contextual manner and an abstracted one. An expression is defined as what a student says about their understanding. A contextual manner was defined as referencing something that is tied to a specific supplied argument or situation. An indicator of a contextual manner would be referencing Pat or Jamie, and any of the argument situations: peanut butter, diamond, python, or hillside for example. An instance of this might be "*And then Jamie said importantly I'm allergic to peanuts, so that's why we know he is sick."* Expression in an abstracted manner was defined as generalizing from a situation. An indicator of an abstraction would be referencing a role of reasoning that is general and not from a specific situation, possibly a speculation such as this one: *"if you don't have enough information then sometimes it doesn't really explain the question whole if you don't have a lot of evidence."*

Salience: Subtle Scientific and Obvious Everyday

As previously stated, salience is defined as the degree of prominence or the ease of recognizing the critical feature or essence (reasoning). One distinction in how the students used the salience in their understanding of reasoning's role was through the subtle scientific context, or the obvious everyday context. The subtle scientific context was defined as referencing one of the scientific arguments. An indicator of a subtle scientific context was referencing the diamond argument or the house on a hillside argument, for instance, *"Pat just said none of the other minerals are able to scratch it and Jamie said why: the diamond is the hardest known mineral, so none of the other minerals can scratch it."* This argument would have been coded as a subtle scientific context, specifically the diamond argument. On the other hand, an obvious everyday context was defined as referencing one of the everyday arguments. An indicator of an everyday context was referencing the peanut butter argument, or the python argument, for instance, *"if you just say my evidence is I ate a granola bar with peanuts in it, you don't really know why that made you sick."* This argument would have been coded as an obvious everyday context, specifically the peanut butter argument.

While analyzing the data with respect to research question 2, a combination of specific argument general interpretations and original transcripts were analyzed to determine what the connection between the scientific and everyday understandings entailed. Using the specific argument interpretation table for a single group, their furthest understanding was in a certain argument context isolated. Then this understanding was compared to how they expressed their understanding in the other contexts. If they had a similar understanding in another context but were less developed, than based on when they discussed this understanding, it was coded as regressing or progressing. Regressing was defined as a decrease in understanding as time went on. So, an indicator of regressing was when a student started with a providing their furthest understanding and then later in the argument applied this understanding to another situation. Progressing was defined as making progress in their understanding. Therefore, an indicator of progressing was when a student started with a weak understanding an over time this understanding developed into their furthest understanding.

Essence: Present or Absent Case

As one of the variations when determining a more granular account of what students could learn about reasoning, the essence was used to highlight reasoning. Essence, as previously discussed, is the common dimension of interest (the reasoning). One distinction in how the students used the essence in their understanding of reasoning's role was through the present or absent case. A present case instance was defined as referencing an argument that contained the essence, reasoning. An indicator of a present case was referencing Jamie's argument because by design, any of his/her arguments contained the essence, for instance, *"And then Jamie said importantly I'm allergic to peanuts, so that's why we know he is sick."* An absent case instance was defined as referencing an argument that was missing the essence, lacking reasoning. An indicator of an absent case was referencing Pat's argument, also by design these arguments lack the essence, for instance *"Pat's doesn't say why she got sick."*

CHAPTER 4

RESULTS

Research Question 1: How Did Students Think About the Role of Reasoning?

Adapted from McNeill's (2006) framework, Figure 3 highlights the multiple ways in which students in this study understood reasoning's role. The Figure is separated into three categories of understanding how reasoning is connected to other components of an argument. The categories were created from the data.

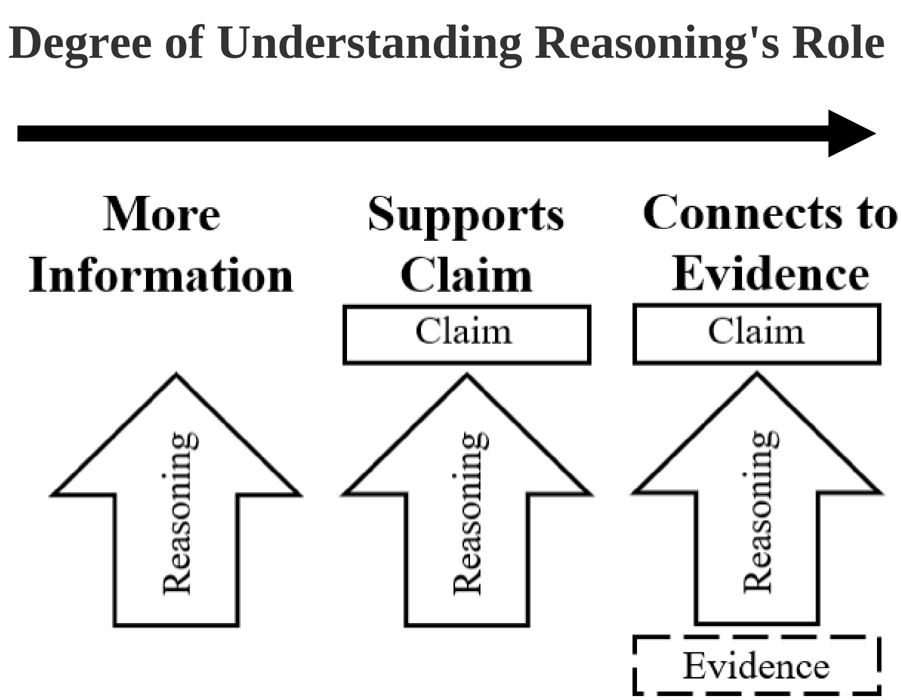


Figure 3: Model of Student's Progression in Understanding Reasoning's Role with Relation to Other Components in an Argument

These three categories shown in Figure 3 address the degrees to which student understanding varied. This section will provide a brief explanation about why the figure is set up in this manner. The second portion of this section discusses a more detailed explanation of each category and how they relate to the different modes of understanding. The three categories shown in Figure 3 differ in understanding. The first category, to the left of the figure, is where students readily noticed that the inclusion of reasoning made the arguments stronger. The diagram is set up in such that there is only a reasoning arrow because students in the *More Information Understanding* only discussed reasoning with respect to being something additional in an argument. Then they attempted to apply their understanding of more information to the argument as a whole and not a specific component.

The second category, shown in the middle of the figure, is a fairly common understanding for student's way of thinking, indicating that the reasoning statement made the claim more plausible by telling why the claim was true. The second category is different from the first in that students include the claim in their expression of reasoning’s role whereas students in the first category did not. Therefore, in the diagram, a claim box is added. However, in the diagram the evidence box is missing because students in the *Connects to Claim Understanding* did not make the connection between the reasoning statement and the evidence.

The last category, shown at the far right of the figure, was infrequent among the students (2/10). This was where students noticed that reasoning relates to the evidence. Acknowledging that reasoning connects the claim and evidence is the most ideal way of thinking about reasoning. Therefore, the diagram for the *Connected to Evidence Understanding* is set up with the evidence as a dashed box because the students were implicit about how reasoning is related to the evidence to explain why the evidence supports the claim.

Strengthening the Argument

As expected, students noticed that the inclusion of reasoning made the argument better. It was evident to all the students that the argument is better supported when the reasoning statement is there. This comes as no surprise; the contrast matrix was designed to highlight this and to foster students in thinking about how reasoning functions with respect to the other components to strengthen the argument. The students noticed reasoning improved the argument by either influencing the argument as a whole or noticing that reasoning connects the different components. However, there were varying degrees to which students could understand how reasoning connects with the other components of an argument.

More Information Understanding

The most rudimentary way in which students thought about how reasoning and its other components relate together was for them to consider arguments holistically (Figure 3). This more holistic thinking aided with understanding how reasoning influences the argument as a whole. Specifically, the students noticed that the inclusion of reasoning added more detail, which makes the argument more understandable. Students' expression of how this additional information functions to make the argument more understandable was diverse. There were two major sub-understandings: (1) it cleared up confusion, and (2) it helps answer the question being asked. They came to these understandings through multiple modes during their discussion but were unable to demonstrate an understand of how reasoning interacts with other components of an argument. Following an explanation of the sub-understandings, three modes of understanding reasoning's role will be discussed: (A) Expression, (B) Essence, and (C) Salience.

<u>Clears up confusion sub-understanding.</u> Students connected reasoning to the argument by noticing that reasoning is additional information which functions to clear up confusion. The following excerpt is an example of how students demonstrate that reasoning clears up confusion because the claim does not make sense when reasoning is not present.

> *She has like more stuff, because like she said that it-it's, like the hardest mineral and he says that my evidence is none of the other minerals are able to scratch it cause that (1) <u>doesn't make sense</u>, because like we (2) don't know what he's talking about like what rock he's talking about.*

Notice how in statement 1, the students recognize that that the argument doesn't make sense, and then in statement 2 they say why they think it doesn't make sense -- because this is a lack of information. However, they do not point out how reasoning is connecting to other components to address this problem.

<u>Answers the question sub-understanding</u>. Student's connected reasoning to the argument as a whole and realize that reasoning helps answer the question being asked. The following example shows how students are vague in their understandings when expressing how the additional information functions.

> *[new row] Jamie adds a little* ***more information*** *that is important. That it's important, <u>helpful to um, answer the question.</u> Yeah, to give it a little bit more evidence besides the evidence that she has. She's got, um, a little more background information.*

Notice how the bold portion of the text highlights where students noticed that reasoning was additional information. The underlined portion highlights where students made their furthest analysis of what the role of this additional information does in an argument. These students describe reasoning as being more information, later referenced as background information;

however, they recognize that this is information that is needed to help answer the question being asked. Similarly, to the first sub-understanding, these students are noticing that reasoning acts in a holistic manner on the argument, but they do not notice how reasoning relates to a specific component of an argument.

Expression. One way in which students noticed that reasoning is additional information was through differences in their expression. Some students used the context of the supplied arguments while others abstracted. The variation students used in their expression of reasoning's role was inconsistent. Table 6 provides examples of two distinctions in students' expression.

Table 6

Example of an Expression Variations within the Additional Information Understanding

Mode	**Variations**	**Transcript**
Expression	Contextual	*cuz you can't just say 'I ate a* ***granola bar*** *with peanuts in it.' If you don't, if they don't know that you're sick or allergic to peanuts.* ***Jamie's*** *argument is more convincing because it [importantly sentence] gives more information about the topic.*
	Abstract	*So, she gives extra evidence of, err, or a conclusion, like a conclusion sentence - like a* ***conclusion sentence that makes it more, more...fun to read****. More importantly, so the teacher can find out more. Like, a conclusion like in a paragraph. Yeah so, she would have a better conclusion than Pat, cuz Pat doesn't have as much...words.*

In the example, students using a contextualized mode used the peanut butter argument and referred to Jamie with an implication to Pat's argument. And the abstracted example does not use a specific context from the activity, instead these students make a generalization about reasoning's role, however, later these students reference Pat.

Essence. Another way in which students varied in their mode of discussing reasoning's role was based on how they used the essence. Students discussed how the argument was affected when the essence (reasoning) was present, which is highlighted in the first row of table 7. In this example, the students notice reasoning's role because of what Jamie's argument has. Other students discussed how the reasoning supports an argument when it is absent, row two is an example of the absent case. In this example, the students notice what the effect on the argument is if the reasoning was not present. In both instances, the students noticed that reasoning is additional information that does something but does not explain what it does. There was no indication that the presence or absence of reasoning was more helpful in determining an understanding of reasoning's role.

Table 7

Example of an Essence Variations within the Additional Information Understanding

Mode	**Variation**	**Transcript**
Essence	Present	*Jamie adds a little more information that is important. That it's important, helpful to um, answer the question. Yeah, to give it a little bit more evidence besides the evidence that she has. She's got, um, a little more background information*
	Absent	*Cuz you can't just say 'I ate a granola bar with peanuts in it.' If you don't, if they don't know that you're sick or allergic to peanuts*

Salience. The last mode that students used to determine reasoning's role as additional information was from the salience of the argument (Table 8). The students either use the obvious everyday context or the subtle scientific context to express how the additional information functions, but neither connect this function to another component. Students were not consistent in what variation of salience was most supportive for them to develop an understanding of reasoning's role, some used the obvious everyday and others the subtle scientific context. Even within discussing an understanding in one context, the students would switch to the other.

Table 8

Example of a Salience Variations within the Additional Information Understanding

Mode	**Variations**	**Transcript**
Salience	Obvious Everyday Context	*But, when he did the peanut allergy, granola bar thing, he didn't say "importantly, he had an allergic reaction". That would have been helpful if they knew, but he didn't say that.*
	Subtle Scientific Context	*I think she gives like more evidence, and she states like if you don't know something like importantly the diamond is the hardest known mineral, so others may not know that and he [pat] is just very simple about it.*

Looking at the two sub-understandings and the three modes, students are not relating reasoning to other components of an argument. Instead students are defining reasoning in terms of its relationship to the argument as a whole. These groups were superficial in their thinking and only pointed out that reasoning is an additional component of an argument and were not specific about what reasoning's role is on a deeper, functional level. These students need the most development in their thinking.

Connected to Claim Understanding

The mid-level understanding of reasoning's role in Figure 3 were students who thought about how reasoning functions with other components of an argument, specifically how it functions with the claim. Most students notice that reasoning made the claim more plausible by describing why the claim was true. The students were able to see that reasoning supports the claim but did not understand how it functioned to do so. An example of this is as follows, *"And* *then Jamie said (1) importantly I'm allergic to peanuts, so that's (2) why we know (3) he is sick."* Notice how in statement 1, the students start off referencing Jamie's reasoning sentence – allergic to peanuts – followed by an explanation of reasoning's role in statement 2 – why – and lastly referenced the claim in statement 3 – he is sick. This sequence shows how students think about reasoning as supporting the claim because being allergic is a reason why the claim, being sick, is true, making the claim believable. What you will notice about this example is that it is not general but meant to be.

Students were able to understand that reasoning supports the claim through multiple modes during their discussion but were unable to understand how reasoning interacts with the evidence. Next, I will discuss three modes of understanding reasoning's relationship to the claim: (A) Expression, (B) Essence, and (C) Salience.

Expression. The first mode for how students connected reasoning to the claim was in their expression. Students either used the context of the argument or abstracted from the arguments. Most frequently, a successful expression of reasoning connecting to the claim, occurred in a contextual manner with both the context of the peanut butter argument (shown above) and the python argument. The following example is a case that uses the python argument to express how reasoning supports the claim:

> *It is giving you like a fact that pulls it all together, like without that, you would not know she was hungry (C) or that [if] she is even dead… if you didn't have it, because umm there trying to make a statement that she's not hungry but without saying that they go months without eating (R), nobody would be able to believe it because it doesn't give the fact.*

In this example, the students' expressed how reasoning (R) makes the claim (C) more plausible by saying that you would not be able to believe the claim – not hungry – without the reasoning – they go months without eating. Reasoning's relationship with the claim in this example is diagrammed in Figure 4.

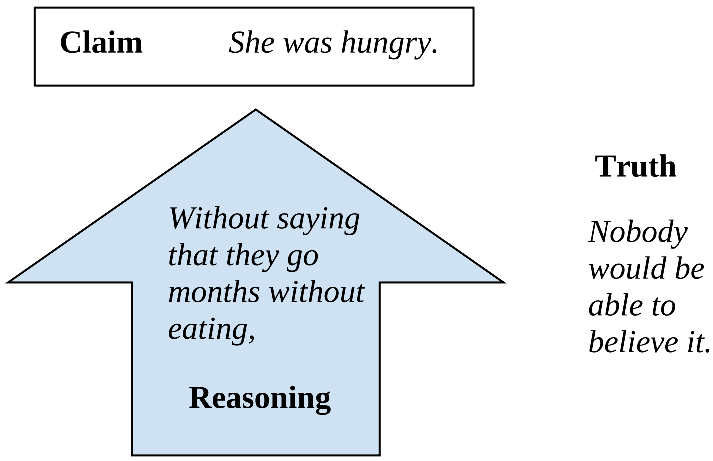


Figure 4: Diagram of Students' Expression of Reasoning's Relationship to the Claim.

The most common occurring pattern of students' expression of reasoning's role starting off referencing the claim, followed by acknowledging the reasoning and lastly coming to an understanding of truth in the claim. A unique aspect about this example is that the students noticed there could be an additional claim -- dead -- when the reasoning is absent. Not only is this group understanding that reasoning makes the claim true, but they are also noticing that reasoning functions to clarify and defend the claim provided because it rules out alternative possibilities. Ruling out an alternative possibility was not a frequent occurrence, so it was not coded for it in the analysis. Notice how even though the students are using the context of the argument, they are still coming to the same understanding as other groups, that reasoning is related to other components of an argument, in this case, the claim.

The other way in which students' expression varied was to abstract. However, an informative abstraction was an infrequent occurrence. The following are two variations of how groups provided an abstracted role of reasoning.

Example 1a: [first comment after reading the first prompting question] *well, it tells why* *… [moves into discussing the diamond argument]*

Example 1b: So, we can say like 'importantly' kinda like grabs the reader like that started word sometimes to grab the reader and then like after they say that, like *they give a reason why they think that**, like they have evidence from like why.*

The underlined portion of the examples show where students made foundational expressions about reasoning's role in an abstracted manner. Even though these students used an abstracted expression of reasoning's relationship to the claim, you can see a similar structure between these students and the students who expressed in a contextualized manner, table 8 illustrates these similarities.

Table 9

Comparison of Pattern When Describing Reasoning's Relationship to the Claim in the Contextual and Abstract Expression

Mode	Acknowledgement of reasoning	Reasoning's role: Explains Why	Reference to the claim	Reasoning's effect
Contextualized	*And then Jamie said importantly I'm allergic to peanuts,*	*so that's why we know*	*he is sick.*	*(we know)*

Table 9. Continued

Abstracted	*So, we can say like 'importantly' kinda like grabs the reader like that started word sometimes to grab the reader and then like after they say that,*	*like they give a reason why*	*they think that, like they have evidence from like why.*	*(grabs the reader)*

In comparing these groups, the group who used an abstracted expression was not specific about what portion of the argument reasoning tells 'why' about. When groups attempted to generalize their thinking was incomplete. For instance, in the table, when the students in the abstracted example said reasoning, *"gives a reason why they think that,"* this could imply that they are referencing reasoning's connection to the claim or the evidence. It is also important to note that they are not inferring anything about the claim's validity as past examples have done. These students are not specific about what reasoning's effect is with relationship to other components, instead they are referencing reasoning's effect on the audience -- *grabs the reader*. Next, I will illustrate that when students discuss the role of reasoning with respect to its presence or absence, they use a similar pattern (acknowledgement of reasoning, explanation of reasoning's role, followed by a reference to the claim) when describing how reasoning supports the claim.

Essence. The second mode of students' connection of reasoning to the claim was to either use the absent case (Pat's argument) or present case (Jamie's argument) to describe reasoning's role. The following is an example of how a student would describe the role of reasoning with the absent case, *"Pat's doesn't say why she got sick."* In the students' expression, they connect reasoning to other components of an argument when they notice that pat is missing an explanation of why the claim – sick – is true. Similarly, an example from the present case, discussed previously, is as follows: "*And then Jamie said importantly I'm allergic to peanuts, so that's why we know he is sick.*" Table 10 shows the similarities in the pattern students took when explaining how reasoning relates to other components even though one is in the absent case and one is in the present case. For instance, in the negative case, they point out that reasoning is missing -- Pat's doesn't -- and then they provide a role of reasoning -- say why -- and conclude with referencing the claim -- she got sick. Similarly, in the present case example the students point out the reasoning sentence -- Jamie said importantly I'm allergic to peanuts -- and then they provide a role of reasoning -- so that's why we know-- and conclude with referencing the claim -- he is sick. Both examples are important because they illustrate that no matter whether the students are expressing their understanding of reasoning role in the present or absent case, the students can notice reasoning's relationship to how it supports the claim. Similarly, to how in the first mode students used the context of different arguments to come to the same understanding that reasoning supports the claim.

Table 10

Comparison of Pattern when Describing Reasoning's Relationship to Claim in the Present and Absent Case

	Acknowledgement of reasoning	Reasoning's role: Explains Why	Reference to the claim	Reasoning's effect: Claim is True
Present Case	*And then Jamie said importantly I'm allergic to peanuts,*	*so that's why we know*	*he is sick.*	*(we know)*
Absent Case	*Pat's doesn't say*	*why*	*she got sick.*	*Implied from why*

<u>Salience.</u> The third mode for how students connected reasoning to the claim was from the salience of the arguments. Students used the obvious everyday arguments and the subtle scientific arguments to express their understanding. Due to the obvious need for reasoning within the everyday arguments, using the everyday context to express their furthest understanding provided the most information about what the students understood about reasoning's role. Notice how in Table 11, the students using the obvious everyday context made a reference to another component of an argument – the claim. However, the students using the subtle scientific context were vague and incomplete in their explanation; it is unclear what reasoning explains 'why' about. More detail on how students used the subtle scientific and obvious everyday contexts as well as frequency are discussed later.

Table 11

Variation in Salience Though the Obvious Everyday Context or the Subtle Scientific Context

	Acknowledgement of reasoning	<u>Reasoning's role: Explains Why</u>	*Reference to another component of an argument*	Reasoning's effect
Obvious Everyday	**Pat's doesn't** <u>say why</u> *she got sick.*			To tell why the claim is true
Subtle Scientific	"<u>It tells why</u>, like **Jamie he says diamond is the hardest known mineral, so nothing is able to scratch it**."			To tell why

While understanding how reasoning connects to the claim manifested in different ways: expressing in the context of the argument or abstracting, through salience of using the present or absent case, it is evident that there is a common structure among all these variations. Students can understand that with reasoning there is support for the claim. However, these students struggle to further explain how reasoning is related to other components.

Connected to Evidence Understanding

The last way in Figure 3 that students' connected reasoning to another component was to connect it to the evidence; however, this was an infrequent occurrence. When students noticed that reasoning was connected to the evidence, they did so in two approaches: (1) reasoning connects the evidence and the claim or (2) reasoning connects to the evidence and claim independently. In both variations, the acknowledgement of the evidence occurred through an implicit reference *("that" and "it").* These are the only examples where the students made a connection to the evidence, therefore this section is not broken down into the various modes of discussing reasoning, instead it will be discussed throughout.

The first sub-understanding of how reasoning is connected to the evidence was to associate reasoning with both the claim and the evidence at once. So, the students understand that reasoning explains why the evidence supports the claim being true. In the following example, the word "that," which is underlined in the excerpt, was interpreted to be an implicit reference to the evidence sentence (E):

> *If you just say (E) 'my evidence is I ate a granola bar with peanuts in it,' you do not really know why <u>that</u> made you sick, unless you knew that person is allergic to peanuts, then now you would know why that person got sick.*

Within their explanation, making this assumption that the word "that" in the excerpt is probably referring to the evidence statement would indicate that this example represents a group who noticed how the reasoning sentence -- being allergic -- rationalizes why the evidence -- eating a granola bar -- could support the claim -- getting sick -- to be true. Analyzing to see if this approach transfers to other arguments with this same group turned out that it was a one-time occurrence. For instance, when this group referenced the diamond and the hill argument, they made a generalization about what they thought the role of reasoning was and did not include the evidence in their thinking. Students in the *Connects to Evidence Understanding* struggle with the gradation in salience. Since the everyday (peanut butter) argument has an obvious need for reasoning the students were able to acknowledge how reasoning could function with other components of an arguments. However, with the subtle need for reasoning in the two scientific arguments, the students struggled to connect reasoning's role with other components. This difficulty was a common occurrence for students. Notice how the student used the essence to help them express their understanding. In this example, the student used both the absent and present case. First, they recognized what happens when reasoning is absent - *if you just say… do not really know why* - but then they connect back to if reasoning was present, then reasoning functions to explain why the claim is true - *now you would know why that person got sick.*

The second sub-understanding for how students notice reasoning is connected to the evidence and the claim was to notice that reasoning acts on each component separately. In the following example, the group notices reasoning's importance with respect to how it functions with the evidence – portion A, and later, they noticed reasoning's role with respect to how it supports the claim – portion B. The students used the salience of the obvious everyday argument to discuss reasoning's role.

> *[answering second prompting question] (A) When it's something like, when it's my evidence is 'I ate a granola bar with peanuts in it,' I mean a lot of people do that, and you don't know that she's allergic, so you don't know why* ***<u>it</u>*** *[the evidence] would matter! (B) Like Jamie takes an extra step and says like she uses extra detail to say why so Jamie*

*gives extra detail to say why **that** [getting sick] happened. Yea she gives extra details to kinda prove maybe her evidence is right. [scratches out some writing] to prove her evidence is right.*

In portion A of the excerpt, the group addresses the essence by mentioning that without reasoning, the claim seems unrealistic when they said, *"I mean a lot of people do that."* With only the provided evidence and no reasoning, the reader does not know the purpose of why the evidence is provided in support of the claim provided, this is evident when the students said, *"you don't know why **it** would matter."* The underlined word 'it' is assumed to be a reference to the evidence because in the sentence prior the students were discussing the evidence sentence. Therefore, the students notice that one of reasoning's roles is to provide support for the evidence sentence alone. Also notice that in portion B of this example, the students can notice how reasoning made the claim true when they said, "*Jamie gives extra detail to say why that [getting sick] happened,"* which was also coded as a connects to claim understanding discussed previously.

An additional observation of this group is that in the end they attempt to abstract but first they revert to a more basic expression of reasoning's role as being additional information - *"extra details".* However, unlike in the more information understanding discussed previously, these students expand upon this abstraction and provide what the role of this additional information is. They state that this additional information's role is to *"prove her evidence is right."* Therefore, the students are noticing a connection between reasoning and the evidence but are not relating it to the claim. For this expression to have been related to the claim, the students would need to say something to the effect of 'reasoning proves her evidence is right (appropriate) <u>for the claim she provided</u>.' In summary of their thinking, they understand that reasoning is extra information to show how the evidence is appropriate to the argument, but not how the evidence is appropriate to the claim. Overall, the students understand that reasoning connects to the evidence and that separately it connects to the claim, but not how the reasoning connects the evidence with the claim.

Overall, students thinking in the *Connects to Evidence Understanding* manifested in different variations: 1) as a connection between the claim and evidence or 2) that there is a connection to the evidence and claim, separately. However, it is still evident that the students came to an understanding that reasoning is related to other components of an argument, similarly to how the students in the *Connects to Claim Understanding* realized. The importance of this finding is that students can include the evidence in their understanding. This thinking shows a deeper understanding of reasoning's role. Specifically, they noticed how the reasoning acts on multiple components of an argument and makes connections between these components. However, the acknowledgement of reasoning's relation to the evidence was scarce for not many groups implicitly or explicitly referenced a connection between the reasoning and the evidence. Of the groups that did reference the evidence, they implicitly noticed that reasoning helps support why the evidence is appropriate and implied that it was appropriate for the claim provided. Unlike the students in the *Connects to Claim Understanding* these students were not as diverse in their expression and use of salience. Both groups were contextual and either struggled to or did not abstract. The salience was also a challenge. During these excerpts, the students did not attempt to apply their understanding to the subtle scientific argument, instead they used the obvious everyday examples.

Understanding how reasoning connects to the claim manifested in different ways: using the context of the argument or abstracting, using the present or absent case, and focusing on the essence. But, it is evident that there is a common structure among all these modes; to notice reasoning supports the claim. However, these students struggle to expand their understanding further with relation to how reasoning connects to other components of an argument.

Research Question 2: How Far Did Students' Thinking Progress with the Scientific Context Arguments Compared to the Everyday Arguments?

Obvious everyday context fostered furthest thinking

As expected, the obvious need for reasoning in the everyday context enabled students to achieve their furthest understanding about reasoning (Table 12). In this study, the everyday context was meant to be easier and allow the students to see the need of reasoning, working as their platform to relate to. However, due to the subtle nature of the role of reasoning in the scientific context, it was harder for students to express their understanding of reasoning. Either students were stuck in the subtle scientific context but then it was easy for them to express in the obvious everyday context, or they had a successful understanding in the obvious everyday but could not extend it to the subtle scientific context. The following examples show the difficulty students had with the subtle scientific context compared to the obvious everyday context.

Table 12

The Category of Understanding Students Reached within the Subtle Scientific Compared to the Obvious Everyday

Connects to Evidence Understanding											Subtle Scientific Context
Connects to Claim Understanding											
More Information Understanding									only	Neither	Obvious Everyday Context
Group	1	2	3	4	5	6	7	8	9	10	

Overall, there were more groups (6/10 in Table 12) that reached a *Connects to Claim Understanding* or *Connects to Evidence Understanding* from the obvious everyday context. Within the groups that used the obvious everyday argument, they either 1) faded in their understanding or 2) made progress. In both instances, notice that the students did not get as far in explaining the role of reasoning with the subtle scientific context compared to how they explained its role in the obvious everyday context.

Regressing from Everyday to Scientific

Students' understanding of reasoning's role in the obvious everyday argument was not enough to anchor and sustain them while discussing reasoning's role in the subtle scientific context. These students' understanding faded as they attempted to transfer their understanding. When students with a *Connects to Claim Understanding* or *Connects to Evidence Understanding* tried to apply their understanding to the subtle scientific argument, they inaccurately applied their pattern. Perhaps the different needs for reasoning between arguments caused the students to struggle keeping a consistent pattern of application to a different argument. This is possibly making them tentative in their thinking. This tentative thinking occurs in the following example as the students struggle to applying their understanding from the obvious everyday to the subtle scientific context,

> "*Pat's she just says, because Pat didn't say why she's allergic to peanuts. She doesn't say why's she's sick, or why none of the minerals are able to scratch it. And then she says, Jamie says loose materials can erode, so the house might fall. And she doesn't say that."*

This example shows students are tentative and therefore regressing in their thinking. The group first successfully applied an understanding that reasoning supports the claim when there was an obvious need for it in the everyday argument -- the peanut butter argument. But when they were applying their thinking in the subtler scientific context – the diamond argument they reference the evidence, not the claim. This may indicate that the subtle need for reasoning in the scientific context is too difficult or they might still be developing their understanding. Lastly, when these students attempt to apply their understanding to another scientific argument with a subtle need for reasoning -- the hillside -- they revert to a surficial understanding that reasoning is more information, by saying that Pat's argument is missing information ("*And she doesn't say that")*. This example is important because it shows that even if a student has a strong understanding in the obvious everyday contexts, it is still difficult to apply that understanding when there is a subtle need for reasoning in the scientific context. Students have difficulty making the leap from the obvious need of reasoning in the everyday context to the subtle need in the scientific context.

Making Progress from Scientific to Everyday

Students made progress in their understanding of reasoning when they started expressing in the subtle scientific context and moved to expressing in the more obvious everyday context.

Perhaps the subtle need for reasoning in the scientific context provided a foundation for further development. Described next is one group who made progress when switching from describing their understanding in the subtle scientific to describing in the obvious everyday context. In this example, at first the students vaguely reference reasoning's role in the subtle scientific *(Example 2a),* and then later used the same terms to discuss reasoning's role within the obvious everyday context *(Example 2b).*

> *Example 2a: Well, it tells why, like he [Jamie] says 'diamond is the hardest known mineral,' so nothing is able to scratch it.*

This example shows how the students within the context of the subtle scientific argument -- diamond -- are vaguely referencing reasoning's role. In this case, they are most likely indicating that reasoning explains why something happens, but they are not clear about what the why explains. Interestingly, Example 2b shows that later in their discussion when they are discussing the argument with a more obvious need for reasoning, the everyday context -- peanut butter -- these same students expand upon what reasoning explains 'why' about to say:

> *Example 2b …and if he just said, 'I ate a granola bar with peanuts in it,' I don't think that would make anyone sick unless you're allergic. Yeah, that's what I was gunna say, if you just say my evidence is 'I ate a granola bar with peanuts in it,' you <u>don't really know why that made you sick</u>. Unless you knew that that person is allergic to peanuts, then now you would know why that person got sick.*

Notice that the students' discussion in Example 2b uses a similar thinking to that used in Example 2a when discussing how the reasoning sentence functions, it explains why something happened. However, in the underlined portion of Example 2b, the students improved their thinking to state that reasoning explains why the claim is true. This group shows that when students are using the scientific argument with the subtle need for reasoning, their thinking prepares them to apply their thinking in the argument with the more obvious need for reasoning, the everyday context. This is not to say that students did not benefit from the subtle need in the scientific context, but perhaps it acts as a building block because they were later more successful with expressing an understanding in the more obvious everyday context. It is also important to note that these students did not come back to modify their thinking in the subtle scientific context once they were successful in the obvious everyday context.

When looking at both situations of regressing and progressing, the results show that students could not easily generate a good understanding of reasoning when it played a subtle role in the scientific context compared to when the need for reasoning was more obvious in the everyday context. Sometimes students could apply their understanding in the obvious everyday and attempted to transfer to the subtle scientific but were unsuccessful, and other times students started an understanding in the subtle scientific but moved on to the obvious everyday context. Both findings together corroborate the quantitative evidence to show the difficulty of the subtle need for reasoning in the scientific context compared to obvious need in the everyday context.

CHAPTER 5

DISCUSSION

<u>Summary of Results</u>

The purpose of this thesis was twofold: to understand a more granular level how students think about reasoning and how to help students identify reasoning in both everyday arguments, where a need for reasoning can be more obvious, and in scientific arguments, where the need for reasoning can be subtle. This study supports the idea that greater structure can be provided to help students begin to understand and appreciate reasoning.

Analysis of the results from research question 1 identified three understandings of reasoning. Students identified as '*More Information Understanding'*, noticed that reasoning is additional information that makes the argument better, but did not say how it functions to do so. In the '*Connects to Claim Understanding' category,* students noticed that reasoning explains why the claim is true. Very few students understood that reasoning connects to the evidence and the claim and were placed in the '*Connects to the Evidence Understanding'* group. Analysis of the results from research question 2 identified that when there is a more obvious need for reasoning in the context of the everyday argument students expressed their furthest understanding of reasoning's role in the argument. The students' understanding either faded when transitioning from an obvious everyday context to the subtle scientific context or made progress when switching from the subtle scientific context to the more obvious everyday context.

Next, current literature is discussed as it applies to this research study to further disseminate the possible implications for teachers. The major points include: (1) students can develop understandings about one of the elements of the Claim, Evidence, Reasoning framework alone, (2) students can understand some variations of reasoning's role in an argument to notice that reasoning has substructures within it and (3) students make the most advances when expressing their understanding through the context of an obvious everyday argument.

Obtaining Understandings of Reasoning When Solitarily Addressed

Much of the current practitioner resources present the claim, evidence, reasoning framework as something that should be used to teach an argument as a whole (McNeill et al., 2006; Hillocks, 2011; Sampson, 2014). However, the purpose of this study was to gain insight into how students could develop a more granular understanding of reasoning when it was a special focus of instruction. The first discussion point is that the results of this study support the idea that students can generate a more granular understanding of reasoning's role with relation to the other components of an argument without teaching about the other components explicitly. In our contrast matrix activity, students are directed to compare arguments as a whole while targeting their attention towards the reasoning statement and noticing what roles reasoning plays in an argument. This showed that it is possible to teach students about reasoning as an isolated component of an argument to develop a more granular account of its role. This finding is beneficial for teachers who may need to break the framework down into more digestible portions, and teach the components separately, when implementing the CER framework. Because teaching about reasoning is challenging, additional focused instruction time is warranted.

Many studies focus on teaching reasoning in conjunction with the other components of an argument, possibly overwhelming the student (Toulmin, 1958; McNeill et al., 2006; Sampson, 2014; Eduran et al., 2004, Eduran et al. 2006; Hillocks, 2011; Nussabaun and Edwards, 2011). However, in some cases, the instruction starts with introducing one component at a time and builds to incorporating all the components. McNeill et al. (2006) focuses on teaching an argument as a whole after an investigation by providing students with scaffolds to supports them generating a reasoning statement. The ADI framework (Sampson, 2014) provides the students with a definition and through practice and peer revisions expects the students' reasoning to improve. Hillocks (2011) also teaches arguments as a whole and expects students to generate a rule (reasoning) for each piece of evidence. Perhaps, in these instances, reasoning has continued to be difficult for students because it was not the focus of the task. The present study showed one way that progress on understanding reasoning's role can be made when it is the only component isolated. However, the present study did not look at how this understanding translates into generating an argument.

A More Granular Account of What Reasoning Is

The literature and practitioner resources present a preconceived notion of what students should think reasoning is, emphasizing that reasoning is a unitary entity. As stated earlier, there are many definitions of reasoning. Most commonly in practitioner resources reasoning is defined as the justification for why the evidence supports the claim, with some resources specifying that the scientific principles should be included. This is consistent with the definition we were expecting from students and most closely aligns with the *Connects to Evidence Understanding* that the students in this study expressed. One exception to this common definition comes from one of the most recent practitioner resources on Argument Driven Inquiry in Science (Sampson, 2014). ADI defines reasoning as being a justification for the evidence: "a statement that explains the importance of the evidence by making the concepts or assumptions underlying the analysis and interpretation explicit." The ADI framework does not explicitly identify reasoning's connection to the claim. It is implied through this framework that if reasoning explains the evidence, and the evidence explains the claim, then reasoning must support the claim. The ADI's definition closely aligns with *Connects to Evidence Understanding* in this study. The results showed that students generated varied and incomplete understandings of reasoning's role with more detailed descriptions than the current literature provides. It is important for teachers to realize that these variations exist, and that students do not only see reasoning as a unitary entity. Understanding these variations will help teachers be able to identify when students are struggling with a partial understanding of how reasoning supports an argument and know how to scaffold instruction when their students are developing their understanding of reasoning. Next, I outline some strategies for teachers when this happens.

Probing Questions

This section presents two ways for classroom teachers to help students further their understanding of reasoning. First, when teachers recognize a student with an incomplete understanding, they should ask probing questions to refocus the students' attention to the complete role of reasoning. Researchers at an educational research institution, TERC, designed productive discussion strategies, referred to as Talk Science. This method of discussion recommends nine talk moves to promote discussion in the classroom (Resnick et al., 2010). These discussion probes would be helpful to redirect student thinking and to focus students' attention on providing their own evidence and reasoning about their understanding of reasoning. Some specific example of how these talk moves could be used and turned into prompting question are presented next. The sample probing questions are organized by the understanding category students are currently at.

(1) When students notice that reasoning is more information, some sample prompting questions could be, "Can you explain more about what this additional information does?" and, "Is this more evidence? Or might it be something else?" Questions such as these can help to refocus the students' attention to the role of reasoning and move past the superficial observations they are currently making.

(2) For students noticing that reasoning tells why the claim is true, a sample prompting question could be, "You mentioned the 'importantly' sentence connects to the claim, is there another part of the argument that this sentence relates to? How is it related to that component?" Much of the difficulty for students in this group is that they are not relating the reasoning to the evidence. Unlike much of the literature and practitioner resources, the ADI framework's definition of reasoning directly relates it to the evidence. Since they do not direct the student's attention towards how the evidence relates to the claim, a possible strategy would be to direct the student's attention to the evidence and reasoning; then, ask the student to explicitly explain how those are related.

(3) And lastly, for students who understand that reasoning connects to the evidence, questions can be focused towards the students' implicit nature of discussion. The difficulty with these students is determining what they are being implicit about. When analyzing the data, it was difficult to know if they were talking about the real evidence sentence or the reasoning sentence. Another issue was that students like to say '*it'* and '*that'* throughout their discussion. To clarify what they were talking about, this study

assumed that the '*it'* and '*that'* would refer to the sentence prior, which in some cases was the evidence. For a teacher to distinguish which sentence is being referred to, the teacher could possibly ask a clarifying question: "I think you are referencing the second bullet is that so?" or, "can you repeat what you just said with an explicit reference to how each bullet relates to each other?" or, "can you point to the sentences you are talking about?" This could help to identify which sentence they are referencing.

Other Contrasting Case Scenarios

The second approach to supporting students developing their understanding of reasoning further might be to contrast differences in mock student understandings. The categories of understanding from this study could be used as sample student responses. Students would then evaluate mock student's thinking. For instance, there could be contrasts between the *Additional Information Understanding* and the *Connects to Claim Understanding*. In this contrast, there would be a scenario where a student describes reasoning as just additional information, and then contrast that with a student that describes reasoning as supporting the claim. It might say: "This one student wrote that reasoning is more information in an argument; they said, 'it is more detail.' But this other student said that the more information makes the claim more believable when they said, 'it explains why the claim is true.'" Afterwards students could process the differences in the mock student thinking by answering probing questions such as: "what is the difference in understanding between what these sample students are saying? Which do you prefer and why?" This same approach could be used between the *Connects to Claim Understanding* and the *Connects to Evidence Understanding*.

Connection from the Obvious Everyday to the Subtle Scientific

I found that students attempt to connect the obvious everyday context with the subtle scientific context. This study showed that when students are generating a more granular account of reasoning's role, they made the most advances with their understanding thought the obvious everyday arguments with some attempt to apply this understanding to the subtler scientific arguments. However, students' progress varied. Connecting between the everyday and the scientific developed in two ways. Some students developed an understanding of reasoning in the everyday context and then regressed in this understanding when using the scientific context. On the other hand, some student made progress when starting with the scientific and attempting to connect their understanding to the everyday context. The analysis showed that when making connections between the everyday and scientific context, applying an understanding to the scientific argument was not as readily done and often resulted in a lesser quality understanding.

From both the regression and making progress approach, students have difficulty with developing an understanding of reasoning from the scientific context. Perhaps it is the abstract nature of the arguments, the need for reasoning, or that students lack the content knowledge. This is valuable for teachers to know because they can provide more support when students are transitioning into developing an understanding of reasoning from the scientific context. Past studies (Aufschnaiter et al., 2008; McNeill et al., 2006) have emphasized that content knowledge and familiarity with the components of an argument separately are not enough, students need to be proficient in both to have successful scientific arguments.

Based on the results of this study, I present two ways in which a task could be designed to minimize the leap from everyday and scientific context because it is still important to focus connecting the everyday and scientific arguments, to learn about reasoning. McNeill and Krajcik's book series (2012) recommend for students to compare the scientific and everyday contexts because "discussing the similarities and differences can help them [students] understand how science is a distinct discourse with its own norms in terms of how to justify a claim."

Foundation in Everyday

Since I found that students had an easier time isolating the understanding of reasoning role thought the obvious everyday context, I present having students gain a solid understanding of reasoning's role in the everyday context by contrasting multiple everyday arguments before analyzing a scientific one. Perhaps then they will have more traction when they apply their understanding to the scientific context.

Scientific More Comparable

In the present study, the scientific context arguments were difficult and the need for reasoning was subtle. Perhaps more headway could be made in tasks connecting everyday arguments and scientific arguments where the scientific scenarios are not as hard. If each argument had the same need for reasoning this could elicit more use of the scientific context in student's understandings.

CHAPTER 6

CONCLUSION

The main concern of this study was that students struggle to provide reasoning in their scientific arguments. This study focused on two purposes: to gain insight into the more detailed understanding of reasonings role students can develop than the current literature defines and gain insight into how students connect the everyday context with the scientific context. With respect to the first purpose, students developed a more granular account of reasoning's role with relationship to how it is connected to other components of an argument. And with respect to the second purpose, students either developed an understanding of reasoning in the everyday context and then faded in this understanding when connecting to the scientific context, or the students made progress when attempting to connect the scientific arguments with the everyday contexts.

The results showed that through contrasting cases, students understand a spectrum of reasoning's role. This variation helped address additional substructures of reasoning's role that students understand, which can aid teachers in supporting their students or with developing curricula. However, prompting questions from teachers are still needed to push towards a deeper level of understanding reasoning's role in an argument.

This study took an intense analysis into students' cognitive output regarding reasoning's role. Continuing research on this topic could focus on directing students' attention towards the connection of reasoning and the evidence. Sample argument creation requires more precision on the need for reasoning in the arguments, to ensure that is not the factor causing the difficulty transferring from the everyday to the scientific and vice versa.

REFERENCES

Aufschnaiter, Erduran, Osborne, Simon (2008) Arguing to Learn and Learning to Argue: case Studies of How Students' Argumentation relates to their Scientific Knowledge. *Journal of Research in Science Teaching, 45(1),* 101-131.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International journal of science education*, *22* (8), 797-817.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94(5),* 765-793.

Bogdan, R. C., & Biklen, S. K. (2007) *Qualitative research for education: An introduction to theories and methods* (5th ed.). Boston: Pearson Education.

Corbin J., & Stratus, A. (2015) Basics of qualitative research: Techniques and procedures for developing grounded theory (4^{th} ed.). Thousand Oaks, CA: Sage.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84,* 287–312.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38(1),* 39-72. http://doi.org/10.1080/03057260208560187

Charmaz, K. (2002). Qualitative interviewing and grounded theory analysis. In J. F. Gubrium & J. A. Holstein (Eds.), *Handbook of interview research: Context & methods* (pp. 675-94). Thousand Oaks, CA: Sage.

Charmaz, K. (2008). Grounded theory. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (2nd ed., pp.81-110). London: Sage.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education, 88(6),* 915-933.

Erduran, Ardac, & Yakmaci-Guzel (2006). Learning to Teach Argumentation: case Studies of Pre-Service Secondary Science Teachers. *Eurasia Journal of Mathematics, Science, and technology Education, 2(2),* 1-14.

Hillocks, G. (2011). Teaching Argument Writing, Grades 6-12: Supporting Claims with Relevant Evidence and Clear Reasoning. Heinemann, Portsmouth, NH.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., & Fredericks, J. (1998). Inquiry in project based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences*, 77, 317–337.

Kuhn, D. (1991). The skills of argument. New York: Cambridge University Press

Kuhn, D. (1993). Science as Argument: Implications for teaching and Learning Scientific Thinking. *Science Education,* 77(3), 319-337. http://doi.org/10.1002/sce.3730770306

Lizotte, D. J., Harris, C. J., McNeill, K. L., Marx, R. W., & Krajcik, J. (2003, April). Usable assessments aligned with curriculum materials: Measuring explanation as a scientific way of knowing. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Lizotte, D. J., McNeill, K. L., & Krajcik, J. (2000). Teacher Practices that Support Students' Construction of Scientific Explanations in Middle School Classrooms Teacher Practice, 310–317.

McNeill, K. L; Krajcik, J. S. (2008). Inquiry and scientific explanations: Helping students use evidence and reasoning. *Science as Inquiry in the Secondary Setting*, 121–134.

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education*, *93*(2), 233-268.

McNeill, K. L. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of Research in Science Teaching, 48*(7), 793-823.

McNeill, K. L., & Krajcik, J. S. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In M. Lovett & P. Shah (Eds.), *Thinking with data: The proceedings of the 33rd Carnegie symposium on cognition.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

McNeill, K. L., & Krajcik, J. S. (2012). *Supporting grade 5-8 students in constructing explanations in science: The claim, evidence, and reasoning framework for talk and writing*. Boston, MA: Pearson Education, Inc.

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences, 15*(2), 153-191.

National Research Council. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press, 2012.

National Research Council. (2000). *How people learn: Brain, mind, experience, and school: Expanded edition.* National Academies Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States (Life Sciences). Retrieved from http://www.nextgenscience.org

NSB (National Science Board) (2007). A national action plan for addressing the critical needs of the US science, technology, engineering, and mathematics education *system.* National Science Foundation.

Nussbaun & Edwards (2011). Critical Questions and Argument Stratagems: A Framework for Enhancing and Analyzing Students Reasoning Practices. *Journal of the Learning Sciences.* 20(3), 443-488.

Osborne, J. (2010). Arguing to Learn in Science: The Role of Collaborative, Critical Discourse. *Science.* 328, 463-466.

Osborne, Erduran, & Simon (2004). Enhancing the Quality of Argumentation in School Science. *Journal of Research in Science Education,* 41(10), 994-1020. http://doi.org/10.1002/tea.20035

Osborne, & Patterson (2011). Scientific Argument and Explanation: A necessary Distinction? *Science Education*, 627-638.

Resnick, L. B., Michaels, S., & O'Connor, M. C. (2010). How (well-structured) talk builds the mind. In D. D. Preiss & R. J. Sternberg (Eds.), *Innovations in education psychology: Perspectives on learning, teaching, and human development* (pp. 163-194). New York, NY: Springer Publishing Company.

Reznitskaya, A., Anderson, R. C., & Kuo, L. J. (2007). Teaching and learning argumentation. *The Elementary School Journal, 107(5),* 449-472.

Robertshaw, B., & Campbell, T. (2013). Constructing arguments: Investigating pre-service science teachers' argumentation skills in a socio-scientific context. *Science Education International*, *24*(2).

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41(5),* 513–536.

Sampson, V. (2014). Argument-driven inquiry in biology: Lab investigations for grades 9-12. NSTA Press.

Sampson, V., & Clark, D. B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education, 92(3),* 447–472. http://doi.org/10.1002/sce.20276

Sampson, V., Grooms, J., & Walker, J. P. (2011). Argument-Driven Inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education, 95(2),* 217-257.

Schwartz, D. L., & Bransford, J. D. (1998). A Time For Telling. *Cognition and Instruction, 16 (4),* 475–5223. http://doi.org/10.1207/s1532690xci1604_4

Schwartz, D. L., Chase, C. C., Oppezzo, M. a., & Chin, D. B. (2011). Practicing versus inventing with contrasting cases: The effects of telling first on learning and transfer. *Journal of Educational Psychology, 103(4),* 759–775. http://doi.org/10.1037/a0025140

Schwarz, B. B., Neuman, Y., Gil, J., & Ilya, M. (2003). Construction of collective and individual knowledge in argumentative activity. *The Journal of the Learning Sciences, 12(2),* 219-256.

Shemwell, J. T., Chase, C. C., & Schwartz, D. L. (2015). Seeking the general explanation: A test of inductive activities for learning and transfer. *Journal of Research in Science Teaching, 52(1),* 58–83. http://doi.org/10.1002/tea.21185

Stratus, A., & Corbin J. (2015) *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage.

Toulmin, S. (1958). *The uses of argument*. Cambridge, England: Cambridge University Press.

van Gelder, T.J. (2000). Learning to reason: A Reason!-Able approach. *Cognitive Science in* Australia: Proceedings of the Fifth Australasain Cognitive Science Society Conference.

Yerrick, R. K. (2000), Lower track science students' argumentation and open inquiry instruction. *J. Res. Sci. Teach.*, *37*, 807-838. doi:10.1002/1098-2736(200010)37:8<807::AID-TEA4>3.0.CO;2-7

APPENDIX A: STUDENT ACTIVITY PACKET

<u>Pre-Assessment</u>

In science class, Pat and Jamie each tested an unknown mineral. They both decided that it was calcite. They wrote arguments that it was calcite based on the evidence they found. Here are their arguments:

Pat's	**Jamie's**
This mineral is calcite. I saw it fizz in contact with acid.	This mineral is calcite. I saw it fizz in contact with acid. Calcite is known for fizzing with acid.

Is one student's argument more convincing than the other, or are they equally strong? Circle one.

- Pat's argument is more convincing
- Jamie's argument is more convincing
- The arguments are equally convincing

Explain why you chose this answer

____

____

____

Warm-Up A

A	B
A dinner at a fancy restaurant	A dinner at McDonalds
Walking	Driving
A Turtle	A Cheetah

1. Describe a single overall difference that makes Column B different from A.

____

____

2. What did you do to figure out your answer?

____

____

Warm-Up B:

A	B
stairs	escalator
axe	chainsaw

Ask for another row if you would like another example

1. Describe a single overall difference that makes Column B different from A.

____

____

2. What did you do to figure out your answer?

____

____

In the Table below, Jamie's arguments have an extra sentence, starting with "importantly."

1. Compare Jamie's and Pat's arguments. Make a single overall explanation for how the "importantly" sentence make Jamie's arguments more convincing than Pat's arguments.

____

Pat's	**Jamie's**
• I know the mineral is diamond. • My evidence is none of the other minerals are able to scratch it.	□ I know the mineral is diamond. □ My evidence is none of the other minerals are able to scratch it. □ Importantly, diamond is the hardest known mineral, so other minerals don't scratch it.
□ I think I am going to get sick. □ My evidence is I ate a granola bar with peanuts in it.	□ I think I am going to get sick. □ My evidence is I ate a granola bar with peanuts in it. □ Importantly, I am allergic to peanuts.
□ We should not build the house on the hillside. □ My evidence is the hillside is made of loose materials.	□ We should not build the house on the hillside. □ My evidence is the hillside is made of loose materials. □ Importantly, loose materials can erode, so the house might fall.
□ Becky, our class' ball python, is probably not hungry. □ My evidence is she ate three weeks ago.	□ Becky, our class' ball python, is probably not hungry. □ My evidence is she ate three weeks ago. □ Importantly, we know ball pythons typically go months without eating.

Ask for another row if you would like another example

2. Leaving off the importantly statement makes Pat's arguments not as convincing as they should be. Why?

____

____

Post-Assessment

In science class, Pat and Jamie each tested an unknown mineral and decided that it was calcite. They wrote arguments that it was calcite based on the evidence they found. Read their arguments and answer the questions below.

Pat's	**Jamie's**
This mineral is calcite. I saw it fizz in contact with acid.	This mineral is calcite. I saw it fizz in contact with acid. Calcite is known for fizzing with acid.

Is one student's argument more convincing than the other, or are they equally strong? Circle one.

- Pat's Argument is more convincing
- Jamie's Argument is more convincing
- The arguments are equally convincing

Explain why you chose this answer

____

____

____

Including reasoning in an argument

Two students wrote arguments. The arguments were the same except one argument had reasoning and the other did not. What is it about including reasoning in arguments that makes them better?

____

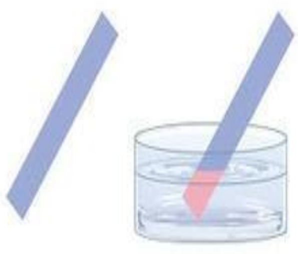
____

____

Making Skyler's argument more convincing:

Skyler wanted to test if an unknown liquid was an acid or a base. Skyler used litmus paper to test it. Skyler knew that litmus paper turns red when put in acid. When Skyler put the litmus paper in the unknown liquid, it turned red.

What would be a possible extra sentence to add to Skyler's argument to make it more convincing?

Skyler saw the litmus paper turn red in the liquid. 	Skyler's Argument: I think the unknown liquid is an acid. My evidence is that the litmus paper turned red when I put it in the liquid. Possible extra sentence to make Skyler's argument more convincing: ____ ____

APPENDIX B: INTERVIEWER PROTOCOL AND SCRIPT

Protocol Order:

1. Intro question on calcite (acid only). Q: Which one is better (A,B,Both), Why?)

2. Warm-up (2x3) (speed)

3. Warm-up (2x3) (size) (introducing concept of adding more arguments)

4. Contrast Matrix

5. Video

6. Post - same as Intro

7. Including reasoning in an argument

8. Skylar's Argument (Making an argument more convincing)

Warm-Up A

A	B
A dinner at a fancy restaurant	A dinner at McDonalds
Walking	Driving
A Turtle	A Cheetah

After Activity is Finished: In looking at this Table, you noticed that column A was slow and column B was fast. To see this, you looked at all of the things in A together and found something in common, and then compared it to column B.

The idea of slow and fast had to work for each row, not just for the cheetah, but also for driving and dinner at McDonalds.

On the next activity, I want you to keep this idea of having the pattern work for each pair of rows in mind.

Warm-Up B (see page 8 for cutouts)

A	B
stairs	escalator
axe	chainsaw
a breeze	a fan
canoe	motor boat
doors at home	automatic doors at the store
hand screwdriver	electric screwdriver

Before starting activity: This is a warm-up for the next activity. While answering the question, I have 4 extra rows that will help you if you need, so let me know if you would like another row.

After working through first extra example provided: Did this new example help you better understand the original pattern you found? Would you like another example?

Do they ask for another row before beginning to write?

> **No**: Okay, let me show you this one I would have shown you anyways before you write anything down.
>
> **Yes:** Before giving it to them, ask: What do you think the pattern is so far? [I don't know is OK].

If they get it right:

> Confirm that the answer is correct and that the answer had to apply to each row. Not just for the [easy ones] but for the [harder one] as well. See correct answer version below.

If they get it wrong:

> Let the students know they were close, but the answer is…. Walk them through how to answer the question correctly making sure they see that the answer had to apply to each row.

After they finish answering/working: You noticed a difference between the columns. Column B has something that Column A is missing. The difference you noticed was a motor. Column B is a motorized version of Column A. To see this, you looked at all the things in A together and found something in common, and then compared it to column B. When you initially looked at the first row you might not have seen a pattern, but after looking at say, 2, 3 or 4 the pattern might have become clearer.

On the next sheet I give you, you're going to do the same process you used here to look at two student arguments.

When you are finished with the next sheet, you will be just about done with our session, so take your time and work hard to make your answers as good as possible.

Contrast Matrix Activity (see the last page for cutouts):

• I know the mineral is diamond. • My evidence is none of the other minerals can scratch it.	• I know the mineral is diamond. • My evidence is none of the other minerals are able to scratch it. • Importantly, diamond is the hardest known mineral, so other minerals don’t scratch it.
• I think I am going to get sick. • My evidence is I ate a granola bar with peanuts in it.	• I think I am going to get sick. • My evidence is I ate a granola bar with peanuts in it. • Importantly, I am allergic to peanuts.
• We should not build the house on the hillside. • My evidence is the hillside is made of loose materials.	• We should not build the house on the hillside. • My evidence is the hillside is made of loose materials. • Importantly, loose materials can erode, so the house might fall.
□ Becky, our class’ ball python, is probably not hungry. □ My evidence is she ate three weeks ago.	□ Becky, our class’ ball python, is probably not hungry. □ My evidence is she ate three weeks ago. □ Importantly, we know ball pythons typically go months without eating.
□ That rock is a sedimentary rock. □ My evidence is it has a lot of shell pieces in it.	□ That rock is a sedimentary rock. □ My evidence is it has a lot of shell pieces in it. □ Importantly, the only way that shell pieces get into rock is by forming sediment layers
• I know there are too many people in our class. • My evidence is that we have 25 people.	• I know there are too many people in our class. • My evidence is that we have 25 people. • Importantly, my school permits only 20 people in a class to prevent overcrowding.

Before starting activity: For this activity, I want you to use the same process you did for the last one. While answering the question, I have 4 extra rows that will help you if you need, so let me know if you would like another row.

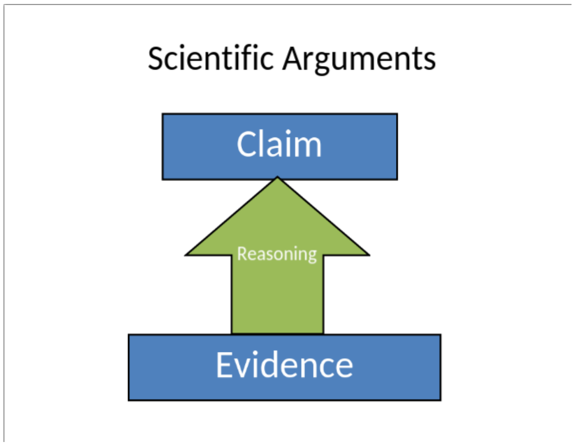
After working through the first example provided: What do you think the pattern is so far?

> I**f they say NO more examples**: Okay, let me show you this one I would have shown you anyways before you write anything down.

If they say YES: Did this new example help you better understand the original pattern you found? Would you like another example?

Once Activity is finished: You guys noticed a pattern between the columns. The pattern you noticed was that Jamie's arguments … [restate what they gave as a response]. I'd like to draw your attention to the importantly statement, the importantly statement adds something to the argument. This "thing" is called reasoning. [show them the claim, evidence and reasoning sheet, then say...] In an argument, you make a claim and support it with evidence. Reasoning is used to connect your evidence with the claim. Without reasoning, your argument is not believable.

[pick an argument that they used the most as your example]
For the ______________ argument,
your claim is __________________.
your supporting evidence is ______________________.
the reasoning is ________________________.
but, without reasoning, you do not have a reason to believe… [evidence]



<u>Video</u>
Now I am going to show you a video that has another example that further explains the importance of reasoning.

After they watch Video: What did you learn from watching the video? Talk to each other about your answer. Did you learn anything else?

<u>Post-assessment</u>
[Prompt: What is the difference between the two arguments? How does this difference make Jamie's more convincing?]

<u>Finish with the acid question</u>

<u>Debrief</u>

For Cutting Up

Warm-Up B

a breeze	a fan

canoe	motor boat

doors at home	automatic doors at the store

hand screwdriver	electric screwdriver

Contrast Matrix

• We should not build the house on the hillside. • My evidence is the hillside is made of loose materials.	We should not build the house on the hillside. My evidence is the hillside is made of loose materials. Importantly, loose materials can erode, so the house might fall.

• Becky, our class' ball python, is probably not hungry. • My evidence is she ate three weeks ago.	Becky, our class' ball python, is probably not hungry. My evidence is she ate three weeks ago. Importantly, we know ball pythons typically go months without eating.

• That rock is a sedimentary rock. • My evidence is it has a lot of shell pieces in it.	That rock is a sedimentary rock. My evidence is it has a lot of shell pieces in it. Importantly, the only way that shell pieces get into rock is by forming sediment layers

• I know there are too many people in our class. • My evidence is that we have 25 people.	• I know there are too many people in our class. • My evidence is that we have 25 people. • Importantly, my school permits only 20 people in a class to prevent overcrowding.

BIOGRAPHY OF THE AUTHOR

Grace Gonnella was born in Bangor, Maine on March 2, 1992. She was raised in Old Town, Maine and graduated from Old Town High School in 2010. She attended the University of Maine, Orono and graduated in December 2013 with a Bachelor of Science in Biology. She entered the Master of Science in Teaching program at The University of Maine in the Spring of 2014. During her initial semester, she participated in an internship at the Jackson Laboratory in Bar Harbor, Maine. Afterwards she returned to the University of Maine campus to complete her coursework. Part way though her program she was hired as an 8th and 9th grade Physical and Earth Science teacher at Penobscot Valley High School in Howland, Maine in September 2015. She continued to work on her thesis and teach. Currently she is the STEM teacher at Brewer High School, Brewer, Maine, teaching engineering courses and all levels of physics. Grace plans to stay in Central Maine as a teacher. Grace Gonnella is a candidate for the Master of Science in Teaching degree from The University of Maine in August 2018.