Contrast Dependent Knowledge Development in Contrast Supported Scientific Observation

Maura B. Foley
University of Maine, maura.foley@maine.edu

Follow this and additional works at: https://digitalcommons.library.umaine.edu/etd

Part of the Educational Assessment, Evaluation, and Research Commons, Educational Psychology Commons, Outdoor Education Commons, Science and Mathematics Education Commons, and the Secondary Education Commons

Recommended Citation
https://digitalcommons.library.umaine.edu/etd/2798

This Open-Access Thesis is brought to you for free and open access by DigitalCommons@UMaine. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of DigitalCommons@UMaine. For more information, please contact um.library.technical.services@maine.edu.
CONTRAST DEPENDENT KNOWLEDGE DEVELOPMENT IN CONTRAST
SUPPORTED SCIENTIFIC OBSERVATION

By
Maura Bernice Foley
B.S. Bates College, 2009
M.S. University of Maine, 2015

A THESIS
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Teaching

The Graduate School
The University of Maine
August 2017

Advisory Committee:
Jonathan T. Shemwell, Assistant Professor of Education, Advisor
Michael C. Wittmann, Professor of Physics
Daniel K. Capps, Assistant Professor, College of Education, University of Georgia
Knowledge of contrasts between phenomena can influence how people think and reason about them, so learning contrasts is important in school science. Building knowledge through a process of construction is a common framework through which school science is taught. However, telling phenomena apart through differentiation also plays an important role in learning and may be underused as a teaching framework. An effective way to learn contrasts is to use them to perceptually differentiate similar-looking phenomena presented side-by-side. However, little is known about the persistence/usefulness of knowledge generated during perceptual differentiation over short periods of time and its usage in student reasoning within an argument. This study addresses this issue through the use of a sample “ID activity” in which participants are shown a side-by-side presentation of two species and asked to identify them using two sets of contrasts. Student thinking was monitored through the collection of 10 student
think-alouds. Results show that once a contrast statement is made it is repeated. These initial observations and repeats coalesce to form the students contrast dependent knowledge of the species. This shows that not only is perceptual knowledge persistent over long periods time, as established in previous studies, but it persists within a short activity. Furthermore, in most instances the restatements are used as a part of rebuttal within an argument. Understanding the nature of knowledge gained from contrast-supported scientific observation has implications for the usage of contrast activities in school science.
ACKNOWLEDGEMENTS

First of all I would like to thank my advisor Dr. Jon Shemwell for all of the time, guidance, and effort he has devoted to the success of my Masters and my continued learning in this field. I appreciate your dedication to helping me navigate the hurdles of doing research in a new field. I am excited to bring the practice of collecting education data into my classroom.

I would also like to thank the other members of my thesis committee for their support and guidance through this process. Thank you Dr. Dan Capps for being a part of my committee despite the distance, we miss you here in Maine! Thank you Dr. Michael Wittmann for your helpful feedback during research group and other RiSE events. It has helped keep me motivated and on track.

I would also like to thank all the other members of the RiSE center who have contributed to my success throughout this process. Thank you to Dr. Susan McKay for all the wonderful opportunities you given me a chance to be a part of over the last two years. Thank you to all the attendees of the research group for all your helpful feedback, and to my 2017 cohort for all your support! Also, a huge thanks to all the volunteers who participated in my study.

Finally thanks all the other amazing people who made this possible. Thank you to my Orono friends, Deb, Moira, and Jessamy: I couldn’t have done this without you. Thank you to my family; Peg and John Foley, Caitlin Foley, Megan Foley, Misha, Pat, and Fiona! All your love and support is truly what made this possible! Also a massive thanks to Ian Gallagher! First for all of your love and support, second for being a copyediting guru, and third for living with someone who is finishing their masters for the second time around, which I imagine is still a rather miserable experience. Finally, thanks you all of my lovely friends: Elise, Rachel, Julie Bilodeau, Reva, Henry, Emma, and Sara for helping me relax and all your votes of confidence!
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS...................................................................................................................... iii

LIST OF TABLES................................................................................................................................ vi

LIST OF FIGURES................................................................................................................................ vii

CHAPTER ONE: INTRODUCTION ........................................................................................................ 1

CHAPTER TWO: BACKGROUND ........................................................................................................... 5

  Construction and Differentiation in School Science ................................................................. 5

  Utilization in Educational Resources ......................................................................................... 5

  Educational Psychology Resources ......................................................................................... 5

  Science Teaching Resources ................................................................................................. 8

  Professional Education ............................................................................................................. 11

  Differentiation’s Role in Contrasting Cases ............................................................................ 12

  Conceptual Framework ............................................................................................................ 15

  Differentiation ......................................................................................................................... 16

  Rebuttal ..................................................................................................................................... 17

  Differentiation in School Science ............................................................................................ 19

  Purpose of this Study ................................................................................................................ 20

CHAPTER THREE: METHODS .......................................................................................................... 21

  Context ....................................................................................................................................... 21

  Design ........................................................................................................................................ 21

  Instrument .................................................................................................................................. 25

  Procedure .................................................................................................................................... 27

  Participants ................................................................................................................................. 29
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Contrast Statement IRR</td>
<td>63</td>
</tr>
<tr>
<td>Table 2</td>
<td>Refutation IRR</td>
<td>64</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Building Construction</td>
<td>4</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Schematic of Web Activity</td>
<td>26</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Field Guide</td>
<td>28</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Specimen Photos</td>
<td>28</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Feature Space Matrix</td>
<td>34</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Single Think-Aloud Contrast Dependent Knowledge</td>
<td>41</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Contrast Statement Frequencies and Timing</td>
<td>44</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Contrast and Non Contrast Mentions of Leaf Shape and Flower Orientation Frequency</td>
<td>45</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Frequency of Rebuttal in Argumentation</td>
<td>50</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Processes occurring during the activity</td>
<td>53</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

In school science teachers work towards student development of *precise* rather than vague knowledge. It follows that it is necessary to cultivate our understanding about how people learn in order to best achieve this goal. Many current ideas about how people learn stem from constructivist theories. However, going beyond an awareness of constructivism’s impact on modern pedagogy, practicing teachers need to know specific ways in which students can develop their own knowledge in a school setting. Despite this need, when the ideas of constructivism are translated into guidance for teachers they do not deliver these precise ideas about learning.

It is important for teachers to know about students learn and how they generate knowledge. In science learning, students are often said to “construct” knowledge. This generally informal usage is derived from constructivist theories, which vary in their definition of construction as a learning process (Phillips, 1995). The present study refers to the concept of construction as a metaphor that describes the learning process as opposed to a precise theory for how people learn. The metaphor conveys that knowledge is built from the ground up, put together piece by piece by the thinker (Staver, 1998). During construction learners add new information to their prior knowledge to create new understandings. In this informal usage it can be imagined as similar to physically constructing a building, where previously independent pieces are added to a pre-existing structure. This can be seen in Figure 1, where separate steel rods are put together to make a more complex, layered structure. When added together the individual rods construct a larger unified building.
This metaphorical use of construction stems from the growing and broad body of constructivist literature (e.g., Tobias and Duffy, 2009). Phillips (1995) discusses how constructivism has been elevated from a theory to a “symbolic force.” This force has found its way into materials used to teach science teachers about learning. In these materials, vague ideas about learning by “construction knowledge” are conveyed to teachers (e.g., Baker & Piburn, 1997, Michaels, Shouse & Schweingruber, 2008, Phillips, 1995). Teachers are encouraged to instruct in a way that promotes “construction” so that opportunities for students to learn through this process are created. This is accomplished by employing specific modes of instruction, related to construction, that have been shown to work. For example, knowledge building can be facilitated through talk and writing, so that students can both reflect on and build their ideas (Baker & Piburn, 1997). However, it can be unclear how these activities should promote learning. Furthermore, the process of building knowledge through talk and writing can go awry (e.g., Chen, Park, & Hand, 2016).

What is needed is more precise guidance for teachers about how students construct knowledge, and potentially additional metaphors to convey these ideas. It is important to incorporate a broad range metaphors that may help to fill this gap in precise guidance. However, the present study is focused on one learning process that may be able to fill a portion of this gap. While a constructivist learning process may sometimes be about putting ideas together (i.e., construction) it can also be about learning from the differences between ideas. This process, what psychologists call differentiation, involves telling things apart in order to generate meaning. Through differentiating learners discover the distinctiveness of things or events (e.g., Gibson, 2000). Differentiation is the
operative process in perceptual learning and a key concept in psychology literature, specifically pertaining to how people learn (e.g., Gibson & Gibson, 1955).

Differentiation typically plays a very small role in teacher preparation and practice, but is an area rich in effective modes of instruction. Still, differentiation’s current role is primarily confined to teacher instruction on how children learn during early childhood development. It does not appear in educational psychology texts or science education texts as something that applies to either older children or adults (e.g., Salkind, 2008, Slaven, 2003).

In the present study, I propose that differentiation may also play a key role in science learning. I provide evidence that differentiation can fill a small part of the void in precise guidance for how teachers can facilitate “construction” as a way through which students learn science. However in order for it to do this successfully it is necessary to have precise explanations of the learning processes associated with differentiation so that teachers can understand and apply them in the classroom. There are two key ways in which differentiation is a valuable idea in science education. This role extends far beyond early childhood development into K-12 education and higher education. In order to make use of differentiation in school science we need to develop precise ideas about how it can be used in these environments. Lastly, if differentiation does not lead to knowledge that is useful to learners, then it is perhaps appropriate that it is overlooked.

The results of this study show the role that differentiation can play in student learning. It expands on the metaphors that science teachers and science teacher educators use to describe learning. Under the umbrella of construction as a metaphor differentiation is one precise way in which learners can develop useful knowledge. In
this study I focused on a convenient sample of adult students in higher education to illustrate the value of differentiation for instructional learning. I collected “think-aloud” data during a scientific observation and reasoning activity and used it to characterize both the learning processes that occur and potential knowledge these processes generate during differentiating. The observation activity was structured to create an opportunity for differentiation to occur. Students developed contrast knowledge during differentiation. Contrast knowledge is when a students’ knowledge of one item is dependent on how it contrasts from the alternative. This knowledge persisted in the student thinking throughout the activity. This knowledge was valuable for scientific reasoning, specifically reasoning in arguments. Furthermore, I found evidence that in many instances this knowledge influenced student thinking during argumentation.

Figure 1 Building Construction
CHAPTER 2

BACKGROUND

Construction and Differentiation in School Science

Utilization in Educational Resources

Ideas about construction can frequently be found in educational resources but the role that differentiation plays in student learning appear less frequently. The results of education research are often reinterpreted into the form of textbooks and other educational resources designed to disseminate these concepts among both prospective and practicing teachers. In such education teachers benefit from understanding (1) how students learn, which is addressed by educational psychology resources and (2) best practices for teaching science content. In best practice resources, science content is formulated into curriculums that the designer believes will facilitate learning. Additionally, ways in which students learn are targeted with specific modes of instruction. It is important to investigate what learning processes these materials describe and promote in order to better understand the current role of differentiation in school science. Below I discuss how examples of widely used resources treat the roles of both construction and differentiation in school science.

Educational Psychology Resources. To start, educational psychology courses and resources provide prospective teachers with an introduction to how human learning occurs. This encompasses the psychology of human development and learning, while potentially even branching out into epistemological characterizations of the nature of knowledge and learning. Educational psychology books provide more substantive content, addressing the history and current interpretations of constructivism and its place
in knowledge development. Some of these descriptions are accompanied by modes of instruction, which support ways of learning such as student talk in social constructivism (e.g., Berger and Luckmann, 1991). These resources do not include a description of how differentiation as a mode of instruction may be a part of the construction process. Instead educational psychology resources primarily describe differentiation as a process within perceptual learning that occurs during child development.

Importantly, differentiation is not presented in these resources as a way of learning utilized by young adults or adults (e.g., Salkind, 2008, Slavin, 2003, Srivastava, 2005). Salkind discusses this lack of focus on differentiation in his *Encyclopedia of Educational Psychology* (2008). He points out that both research and resources focus on perceptual development in infants more than adults, and that many introductory educational psychology textbooks include very little information about both sensation and perception (2008). The subsequent review of several introductory educational psychology texts for this study lead to a similar conclusion. Differentiation may be referenced as a skill that distinguishes humans from other species, and Salkind discusses its role in perceptual development of infants. For example, infants use their perception to differentiate between contrasting phonemes. This helps them generate and understand their native language and differentiate phonemes that are not a part of their language (Salkind, 2008). Texts approach differentiation to varying degrees through their discussion of learning and transfer.

In their handbook of education psychology Corno and Anderman have collected contributions on five key research domains in education psychology (2016). I discuss this resource because it puts forth a very current perspective on ideas and strategies
researched in the field of educational psychology. Different then some of the resources above, Corno and Anderman delve into topics relevant to constructing knowledge, and the role perceptual learning may play beyond early child development. For example, in Building Knowledge and Subject Matter Expertise the editors present strategies that help students construct new knowledge in areas such as mathematics and literacy. However, one contributor, Calfee (2016), discusses the role perceptual learning may play in school learning. At the end of this contribution, Calfee highlights a need to develop better understanding of the learning processes underpinning these instances. Furthermore, he emphasizes that researchers in educational psychology play an important role in making existing knowledge of relationships between processes like perceptual learning and transfer better known so that they can be applied in school learning (2016). For example, he suggests how the experience of drawing multiple free-body diagrams may allow students to see structural similarities across examples and facilitate transfer. Calfee discusses this specific example within the broader context of how we think about phenomena that are unobservable. This is a location where differentiation could have been highlighted, as it must have been operative in extracting structure from the free-body diagram, however his focus stayed on perceptual learning.

Calfee also alludes to the role of perceptual learning in a non-school knowledge field, chess. Expert chess players use perceptual learning to understand structure, which generates transferable knowledge. While the process of differentiation is implicated in perceptual learning (Gibson and Gibson, 1955), by focusing on perceptual learning, Calfee unfortunately fails to highlight how differentiation is worthy of much more research.
Science Teaching Resources. After the ways in which people learn are presented in the literature, they are eventually distilled into resources used in both pre-service teacher education and by practicing educators. These resources for teachers neglect differentiation as a way that people can learn. The well-cited book *Constructing Science in Middle and Secondary School Classrooms*, is emblematic of this type of resource. As the title implies, the authors focus on presenting strategies to help students “build” their own knowledge (Baker and Piburn, 2007). They approach these strategies by discussing construction metaphorically—through the lens of constructivist theory—similar to this study. They establish that knowledge is not simply transferred from a teacher to a student and absorbed. Instead, it is in an active process through which students build their own knowledge. The authors synthesize and draw from constructivist theory to suggest that construction is an ongoing process during which learners reorganize their conceptual framework to incorporate new schema. If each new schema represents a new organization of information into categories based on the relationships between these categories, then continually adding schema indicates a growing conceptual framework. A metaphor for this type of construction can be seen in figure 1. The individual steel beam represent new schema. The building that the steel beams are added too represents the learner’s conceptual framework. Both the building and conceptual frameworks change their size and configurations as new steel beams or scheme are added to them.

After setting up their interpretation of constructivism Baker and Piburn (2007) advanced approaches for instruction in this mode. These approaches were explicitly grown from the additive nature of building science through the continual introduction of new schema. Presumably these approaches also hinge upon a learner’s constant
generation of categories from these schema based on the category’s relatedness. Earlier I proposed that differentiation, or understanding based on differences, may be a useful learning process in science. Baker and Piburn’s learning strategies do not address the role that differentiation may play in science education. Depending on the definition of construction used, it is possible that differentiation processes could be considered implicit in a learner’s generation of new categories in which to fit their schema. However, it is important to note that the authors do not present any modes of instruction that may be utilized to harness differentiation in science learning.

There is another emblematic example of the neglect to include differentiation: the broadly distributed resource, Ready, Set, SCIENCE!: Putting Research to Work in K-8 Classrooms (Michaels et al., 2008) was derived from a national effort to distill research on science learning. Similarly to Baker and Piburn (2007), the authors of this resource focus primarily on the idea of construction as the primary way of learning in science. Here, these authors thoroughly explicate “building” on knowledge, interests and experience. They also put forth strategies for building on core concepts over time and using these concepts to build learning progressions. In their strategy teachers help students to build their knowledge, not by just “telling” students information and expecting transfer, but by using four “strands” of science learning. These strands are understanding scientific explanations, generating scientific evidence, reflecting on scientific knowledge, and participating productively in science. This approach is similar to the distillation of constructivism put forth by Phillip (1995). Phillip describes the learner constructing their knowledge using a variety of methods and criteria unique to each individual. He goes further to describe that the knowledge incorporated by these
learners are constructs in themselves. In the sciences, for example, all the existing knowledge was constructed by years of previous thinking by scientists. Learning progressions by Michaels and colleagues (2008), which take core concepts as their diving off point, are reminiscent of Phillips’ description of how construction as a learning process is sometimes used symbolically and as a summation of many constructivist theories.

Michaels et al. are clear-cut in their use of building knowledge as a critical part of learning school science, but again stop short of any discussion of differentiation as a learning process. Among other strategies, they devote a section to learning through talk and argument, a mode of instruction that would align well with social constructivism (Berger and Luckmann, 1992). They do discuss children’s capacity for science learning in the beginning of their book. Here, they mention sophisticated ways of thinking about phenomena that children develop by having direct experiences with their physical environment. These might include watching phenomena occur, and observing items or organisms in their environment. It seems here that the authors are citing many of the same types of early learning mentioned in the educational psychology literature (e.g., Salkind, 2008, Slaven, 2003, Srivastava, 2005). They discuss these apparent perceptual learning processes as a starting point from where educators can plug continued science learning. However, they do not promote these perceptual processes as a continued way of learning. For example, they include a section entitled “Making Thinking Visual” in which they discuss various types of visual representation and how students learn from and show their knowledge with these tools. This would be an excellent place to include differentiation as a learning tool, or teaching using contrasts as a mode of instruction.
However, differentiation is again overlooked as both a stand-alone process and a process that might be contained within the metaphorical learning process of construction.

**Professional Education.** One area where learning through differentiation has been put forth as a critical process is in professional education and training. Repeated sensory exposure to instances of differentiation allow professionals such as pilots, radiologists, wine tasters, and agricultural workers to become experts in their fields (Biederman and Schifffrar, 1987, Kellman et al., 2009). For example, it is useful for a radiologist to observe as many example x-rays as possible as it refines their ability to notice features that are invariant from scan to scan. Biederman and Schifffrar (1987) also found that when given practice with a series of images and directed to look for two contrasting shapes participants were able to sex day-old chicks with similar accuracy to experts. The professional sexers gained their expertise over years of practice, similar to the gustatory expertise of a wine connoisseur who has tasted many wines. The intervention led to the participants being able to gender chicks with accuracy that would have usually taken years of practice. While differentiation’s role in professional education has been well emphasized, there is little evidence that this has led to generating modes of instruction that explicitly target this skill. This echoes the need I raised earlier in my discussion of Calfee and his description of the usefulness of perceptual learning for chess experts (2016). Most importantly, evidence of differentiation’s usefulness has not been promoted in educational settings outside of these specific fields.

Resources such as those I discussed in the three sections above provide important, research-vetted teaching strategies. I do not propose that these strategies are ineffective or that the focus should be on differentiation rather than construction. Rather, it is
important to understand and provide evidence of the role that differentiation and associated modes of instruction may play in science learning and reasoning. This understanding must be developed in order to create precise instructional strategies that promote differentiation.

**Differentiation’s Role in Contrasting Cases**

The limited information about differentiation available in the resources discussed above calls for an examination of what differentiation looks like in a teaching context. One area where there are clear opportunities for emphasis on differentiation as a learning process is in the use of contrasting-cases as an educational tool. Despite the role of perceptual learning in structure extraction in contrasting cases, promoting and/or exploring differentiation was not the primary goal of these studies. The results of these studies are important as they give insight into paths to deep learning and a specific mode of instruction that can be used to target these paths. However, differentiation in these studies appears to be an important stepping-stone along these paths.

Contrasting cases are a tool where learners are presented with multiple alternate instances of a problem, segment of text, image, sound, and so on. These alternate instances range from relatively similar, to significantly different. They are usually presented either juxtaposed or presented to the learner in quick succession. For example participants could be shown two similar math problems side by side, or two written arguments side by side. Furthermore, contrasting case activities are commonly seated within a productive task, such as inventing an index or explanation to cover all the cases (Schwartz et al., 2011).

Perceptual learning and coinciding differentiation likely play key roles in student
ability to exact structure. Schwartz et al.s.’ (2011) contrasting case study focuses on a key science concept: density. They explicitly use the contrasting case structure to help students create single quantitative explanations of the deep structure of the density concept. In order to accomplish this the authors tested one condition where students were given contrasting cases, and one where they were not. In one contrasting case example, students were given three images, each showing two vehicles filled with clowns. Each image represented one company of clowns and students were prompted to develop a crowdedness index for the company. The authors found that students who had to invent with the contrasting cases had a better understanding of the ratio structure of density; furthermore they exhibited more successful transfer of this knowledge to other content. In order to develop their indexes, students had to perceptually differentiate between each set of cars and how crowded they were. The spatial distribution of the clowns worked toward developing a concept of density which could be observed from the two dimensional drawings. The images were presented side by side which allowed students to differentiate certain things, and isolate density as invariant. This study came closer to focusing on differentiation then the previous two I discussed. Differentiation was understood to support generating the crowdedness index. However, the goal was for participants to look for a commonality. Differentiation’s role as a mechanism of learning was not very salient in the discussion of how contrasting cases supported learning and transfer. The authors at least discuss how perceptual learning was operative in students’ noticing information, but do this without digging into how differentiation helped students extract deep structure.

The results of the study by Schwartz et al. (2011) show three things: contrasting
cases are useful in learning; the structure students extracted for observing juxtaposed images was more easily transferred; transfer is desirable in school learning. However, they do not give particular insight into the role differentiation played in this structure extraction. This is because differentiation was used for students to build a single index. As the authors state:

“The directive to make an indexing scheme differs from asking students to explain, draw an analogy, or simply compare and contrast, because it specifically pushes students toward a single, quantitative explanation of the deep structure.”

(p. 3)

The knowledge generated is towards a single unifying concept rather than a concept about the differences across cases. Similarly, in the 2015 study by Shemwell, Chase and Schwartz students were given three side-by-side contrasting cases that were intended to help them generate one concept: changes in a magnetic field can cause current flow through a wire. Contrasting cases allowed students to perceptually observe changes in magnetic field and its orientation relative to the coil. The opportunity for differentiation played a role in students’ successful transfer of the conceptual knowledge they gained. However, like with Schwartz et al., (2011) the focus of this study was on how the contrasting cases helped in the development of unified conceptual knowledge, and differentiation is not highlighted as a way of learning even though it is involved.

Contrasting cases have been shown to be useful in both learning and transfer (e.g., Brandsford and Schwartz, 1999, Rittle-Johnson and Star, 2009). In their 2007 and 2009 studies Rittle-Johnson and Star found that visual comparisons of math problems helped students to gain understanding of the problem solving methods. Furthermore, Rittle-
Johnson and Starr found that using contrasting cases of problem solution procedures was especially effective in increasing students’ conceptual understanding of problems. This was evidenced by increased student fluency applying problem-solving procedures to a broad range of math problems (2009). Engaging in differentiation is often operative within contrasting case studies. For example, using visual processing lets student notice differences in the structure of a math problem. However, the closest they come to discussing differentiation is in their 2007 study in which they briefly mention that when students compared contrasting math problem solutions it helped them to differentiate between key problem features. They primarily focus on how these comparisons can help students to notice similarities across problems without talking about differentiation. The present study seeks to further examine the learning that happens during differentiation and the type of knowledge that it may generate in order to better develop differentiation activities as a precise mode of instruction.

**Conceptual Framework**

An important step toward understanding the role of differentiation is identifying what type of learning is occurring. This study used a differentiation-supportive scientific observation activity to collect data, making perceptual learning the focus. This study specifically looked to determine what sort of knowledge participants generate throughout the observation of contrasts (e.g., what are the products of differentiation). Furthermore, it looked to characterize the process of this knowledge formation and evidence of its usefulness. Throughout this study I used a series of key concepts/definitions that may have alternative meanings in other contexts. In order to develop a conceptual framework, their meanings and background (as used within this study) are discussed below.
Differentiation

Above I discussed the potential importance of differentiation as a learning process in school science. This study focuses specifically on one kind of differentiation: differentiation as a perceptual process. Here I use the term differentiation differently than it is used in developmental literature, where differentiation is discussed in terms of differentiated and undifferentiated ideas (e.g., Carey, 2004, 2009).

When learners engage in differentiation they are learning through perceptual learning. Perceptual learning is when learners generate knowledge by noticing the distinctiveness of things and events through sensory stimulus. This occurs when learners interact with new physical stimulus they have not already responded to. Through differentiating between stimuli learners not only learn how things are distinct, but they also discover invariant properties of these things. Increasing exposure to perceptual stimulus allows the learners to both improve their differentiation skills and refine the detail with which they notice features. Learners incorporate this knowledge of distinct and invariant features into a field of contrasting alternatives (Gibson and Gibson, 1955, Gibson and Gibson, 1969, Gibson, E.J., 2002). For example, an individual may describe the color of all the leafed vegetables in a salad as being green. However, upon observing a box of mesclun mix they may modify their description, noticing that the arugula is light green, the endive is yellow-green, and the spinach is a deeper green. These observations represent additions to their field of contrasting leafed vegetable color alternatives. Without the opportunity to notice the similarities and differences of the leafed vegetables the learner may not generate a concept of the vegetable color as precisely as the one they generated during differentiation.
The example above is based off a process first presented in Gibson and Gibson’s 1955 study where participants look at a series of nonsense images with slight variations. Due to the experience of seeing them side-by-side the participants are able to perceptually differentiate slight differences between the nonsense images (e.g., one squiggle is more tightly nested than another). By noticing these features the participants build a field of possibilities for squiggle qualities that are defined by the squiggles’ differences. This is the learner’s repertoire of contrast knowledge.

Expert repertoires of perceptual knowledge can be gained through practice in differentiation. Experts such as wine connoisseurs, pilots, professional chick sexers, and radiologists all have fields of contrasting alternatives from creating memories of a large series of well-differentiated perceptual knowledge (Gibson and Gibson, 1955, Biederman and Schiffrar, 1987, Kellman et al., 2009). Additionally, as shown by the Biederman and Schiffrar study of chick sexers discussed above, people are able to pick up perceptual information fairly quickly and then make fluent use of them if they have good contrasts to work with. The Gibsons’ believed that this kind of learning might have a role to play in education. Useful, well-differentiated knowledge can be developed through contrast-supported activities, such as the contrasting-cases activities discussed above. The perceptual learning that occurs during the differentiation of contrasting cases may play a role in reducing the time it takes to acquire these expert skills. Harnessing perceptual learning by using contexts that help with transfer and are relevant to learned content can lead to successful learning (Brandsford et al., 1989).
Rebuttal

In the present study, I used student reasoning about evidence as a measure of the influence of the knowledge gained through differentiation. Reasoning is desirable in school science. A common framework used in school science is the Claim Evidence Reasoning (CER) framework. CER products are provided and endorsed by a broad range of educational resource providers including the National Association of Science Teachers, and Pearson (McNeill and Krajcik, 2012). As part of investigating the usefulness of knowledge gained through differentiation this study focuses on a specific type of reasoning: rebuttal. Rebuttal is the description of alternative explanations or claims and then ruling out these claims as a part of reasoning about a claim or hypothesis.

I used rebuttal in this study to show whether or not knowledge was useful to students because generating rebuttal during argumentation is difficult to achieve. School science often includes scientific investigations, and hypothesis testing is an important part of any scientific investigation. Klayman and Ha discuss the role that both confirmation and disconfirmation play in hypothesis testing, and reasoning about hypothesis (1987). They also highlight that humans overwhelmingly favor the use of confirmation and are less likely to use disconfirmation. However, the use of disconfirmation is a key component of rebuttal. In their book on constructing explanations in science McNeill and Krajcik discuss not only CER, but another framework, claim, evidence, reasoning and rebuttal (CERR) (2012). Rebuttal was the fourth component of their scientific explanation framework, tying the claim, evidence, and reasoning of an argument together. In the language of Klayman and Ha, the learner disconfirms the claim during the rebuttal process. This study specifically looks for rebuttal using information derived
from differentiation to rule out alternative explanations. As rebuttal is widely considered to be difficult to achieve (e.g., Klayman and Ha, 1987) this study looks for the presence of rebuttal as evidence of higher order thinking skills. The presence of higher order thinking is an indicator that knowledge gained through differentiation is valuable to the learner. While there are other metrics, which could be used to characterize the knowledge usefulness, I focus on rebuttal because if knowledge generated during differentiation can support a process that is difficult to achieve then this is robust evidence of usefulness.

**Differentiation in School Science**

I propose that it is important to understand more about the processes that occur as a part of differentiation because it plays a role in school science. Developing scientific reasoning is a critical part of science learning, and learning achieved through observation plays an important role in this process. The work of this study springs directly from contrasting cases research. As discussed above using contrasting cases in learning can help students develop deeper understanding with subsequent topics (Schwartz et al., 2011). In addition to impacting learning and transfer, contrasting alternatives learned through differentiation have been shown to have a positive impact on how students think and reason about phenomena, which is important in school science (Kellman et al., 2009). However, the contrasting cases research trails off without directly addressing the role of differentiation as part of this learning process.

This learning through differentiation is developed through perceptual processes, which include discovering the distinctiveness and invariance of things and events, and are a type of meaning derived from the result of perceptual learning (Gibson, 2000). This
study refers to these processes as differentiation, as discussed above. A recent study by Kellman et al., (2009) further showed that targeted perceptual learning activities can, in fact, support the generation of lasting robust knowledge of the targeted topic. This is supported by other research, which shows that experts have a field of contrasting alternatives, which they draw upon when reasoning.

**Purpose of this Study**

The purpose of the study is to characterize the learning processes that occur during differentiation. This was done in an effort to determine if knowledge generated through differentiation is useful to the learner and how it might be used as a mode of instruction. Specifically, this study looked at how the development of knowledge, through differentiation, about even one contrast (as opposed to a field of contrasting alternatives) could lead to better reasoning in subsequent questions within the activity that initially facilitated the perceptual learning. Specifically, this study investigated the robustness of knowledge gained from contrast-supported scientific observation in a species identification activity. New insight into these processes informs the use of contrast activities in school science.
CHAPTER 3

METHODS

Context

In this study I directed adult participants to think-aloud, both while learning new information (through differentiating contrasts), and during their reasoning processes. I then analyzed think-aloud transcripts in order to characterize the learning processes that occurred throughout the activity. During a brief, approximately 10-minute activity, participants learned about two plant species and identified specimens within a web-based interface. Information about the species was presented in a juxtaposed field guide in order to support differentiation. The motivation for the participant was to identify a plant specimen, potentially an invasive species. They could achieve this identification using information about Japanese knotweed and an alternative species, Giant knotweed, learned as a part of the activity. The activity consisted of: 1) a short video, 2.) field guide 3.) specimen photos, and 4.) written-response prompts. Participants completed these sections on their own, one at a time, and I recorded their vocalized thought processes as they completed the activity. The ID activity used a Vital Signs field guide and its respective photographs (vitalsignsme.org). The activity was modified from a version used in a previous study by Shemwell et al. (in preparation).

Design

My goal in designing this study was to reveal a learning process, namely differentiation. In order to accomplish this I used think-alouds collected from participants as they engaged in a differentiation activity. Generally, think-alouds consist of participants verbalizing their thought processes while completing all the activity tasks.
This includes verbalizing thinking about questions, but also verbalizing tasks such as reading prompts, scrolling, looking at photographs and what is noticed about these photographs. This technique is an accepted standard for revealing cognitive processes as people engage in a task (Ericsson and Simon, 1998). These think-alouds generated evidence of learning that occurred during a differentiation process and how learners applied that learning to generate a scientific argument. I relied on the think-alouds to pursue four research questions:

1. What learning processes occurred during contrast observation related differentiation?
2. What knowledge did participants generate by observing contrasts?
3. How easy or difficult was it to construct this knowledge?
4. How useful was this knowledge?

The species identification activity completed by participants consisted of the observation of field guides of two species, which were juxtaposed so that students could differentiate. Information gathered from the field guide could be used to answer a series of questions.

I then used transcripts of these think-alouds to measure the learning processes occurring through differentiation, knowledge generated, ease of generation and its usefulness. I describe the activity throughout which think-alouds were collected, think-aloud protocols, as well as transcript coding in detail below. I discuss the four research questions together, since I used the same tool to address all these questions. The robust content within the think-alouds contain precise information about student thinking which I use to address these research questions. Furthermore, due to the frequent simultaneous occurrence of processes like knowledge construction and its ease of construction, I
frequently discuss results pertaining to multiple research questions together within the result section.

I designed the activity so that it would support the differentiation process. The general structure of the activity the participants completed was as follows: (1) participants watched a short video about Japanese knotweed where they learned that it is an invasive species; (2) Participants viewed juxtaposed field guides of Japanese knotweed and another species, Giant knotweed; (3) students viewed a series of specimen photos; (4) participants were prompted to use specific plant characteristics to identify the plant in the specimen photos. I chose field guide images, which displayed these features clearly, in order to target student thinking about contrasts and to address my research questions. The specific contrasts targeted by this activity were two important trait differences between the species. These were shape and flower rigidity. Juxtaposed images of the leaf shape of Japanese and Giant knotweed, as well as two juxtaposed images and flower orientation from the two species were shown in the field guide. Each image had a short caption under it. However, these captions did not contain any information about leaf shape (e.g., Giant knotweed has heart shaped leaves) or flower orientation (e.g., Japanese knotweed flowers grow upwards from the stem). Captions contained information about characteristics of the species that either could not be observed perceptually, or were the same in both species. These included characteristics such as the flowering season, flower color, and bush height. The survey was designed so that participants could not discern anything novel about perceptual differences between the two species through reading the text. This created an opportunity for perceptual
learning and differentiation to occur using only the photos as students viewed the field guide.

The goal of this study was not to determine if students could correctly identify specimen photos using information they culled from a field guide. Instead, as shown by the research questions, it was to characterize how students were thinking about the contrasts they observed and how they used this thinking as they applied it to the activity questions. Participants were asked to not only ID the specimen but to provide evidence for their choice. This created an opportunity for students to use any knowledge gained through differentiation to generate a scientific argument. Additionally it pushed the answers beyond a “yes/no” and created a time during which the verbalized thinking might provide additional elucidation into how participants were thinking. How and if students used this knowledge during argumentation addresses this study’s question of the usefulness of the knowledge participants developed. The wording of the questions did not include any information about differentiation or any words to prompt noticing of contrasts. Although I delivered the activity to students in a Google survey format, the written student responses were not the primary focus of data analysis. Additionally, an important component of collecting think-aloud data centered on structuring the activity in a way that helped participants to understand how to provide robust think-aloud data.

I used a small sample group, as think-aloud data is rich in evidence of the type of learning processing occurring during activity completion, and sufficient to characterize these processes. Additionally, adult participants were used both as a convenient sample and with the expectation that their thinking processes would be reasonably representative of students in late middle school and upward. The way young children learn using
differentiation is discussed in educational psychology literature and these older learners served as a counterpart to children. If these older learners developed knowledge through differentiation it shows that the use of differentiation should not be confined only to young children.

The adult sample group was also proficient in computer and literacy skills. This allowed me to collect data specifically on how the students were thinking about contrasts and when differentiation occurred, with a reduced likelihood of having to interrupt the activity to provide instruction on how to use the computer or help decode questions for the participants. One of the goals of this study was to explore how modes of instruction using differentiation help students generate useful knowledge in school science. This sample group was adequate to provide general information of how people use and learn from contrast, but using sample groups from a variety of K-12 grade bands would provide deeper insight. Additionally, different age students could engage with contrasts differently than my sample group, as a result of different skills, knowledge, and so on.

**Instrument**

The overall structure of the instrument involved participants first observing attributes of the two species through differentiation as they looked at the field guide. They then observed the specimen photos to see if the attributes matched the target in the field guide. They would then generate an identification argument.

As mentioned in the instructional context and design, the instrument consisted of an activity completed in a web-based format, which involved learning about and identifying a plant specimen. Figure 2 shows a schematic of this activity, which differs from the web-based version in that users needed to scroll from section to section and
could not see all of them simultaneously. The web-based activity was written as a Google form and the video was hosted on the YouTube platform (video credit: Christine Voyer, Gulf of Maine Research Institute). The Google form recorded participant input to multiple choice and free response answers. However, the primarily data set used by this study was their think-aloud outputs. After each participant completed the warm up think-aloud activity a computer microphone was used to record the participant’s utterances throughout the completion of the activity. Recording was stopped after participants hit “submit.” I then transcribed these recordings.

Figure 2 Schematic of Web Activity
Procedure

Before completing the species ID activity I guided participants through a brief think-aloud warm up activity. The goal of this activity was to familiarize the participants with the think-aloud protocol. It also served as an “ice-breaker” to ensure that sufficient verbalization was made during the completion of the primary activity. More details about the think-aloud protocol and test are given later in this chapter.

At the beginning of the investigation the students were presented with a guiding question, which provided context for the subsequent investigation. This was:

“Is Christine’s plant Japanese knotweed?”

They were then prompted to decide if they consented to their data being used in educational research. Then participants watched a short video. In the video, a woman (Christine) talks about how she may have found Japanese knotweed in one of her favorite outdoor locations. Views of a large bush, and more close ups of the plant’s leaves and stems are also shown in the video. As students completed the activity they could return to watch the video if they wished.

After watching the video, participants were presented with a field guide in which the two species were juxtaposed (Figure 3). The images from the two alternative species were presented side-by-side in order to support differentiation, similar to the structure of visual materials in contrasting cases studies. The activity was completed on one scrolling screen so that participants could not look at the field guide, specimen, or argumentation prompt at the same time.

After observing the field guide the participants were shown six photos of an unidentified specimen (Figure 4). They were asked to ID the plant’s species based on
Figure 3 Field Guide

Japanese Knotweed *Fallopia japonica*
Leaves

Look for leaves that are large on a thick bush that grows up to 3 meters tall.

Japanese Knotweed *Fallopia japonica*
Flowers

Look for small creamy white flowers in September and October.

Giant Knotweed *Fallopia sachalinensis*
Leaves

Look for leaves that are very large on a thick bush that grows 2-5 meters tall.

Giant Knotweed *Fallopia sachalinensis*
Flowers

In the early fall look for clusters of small white flowers.

Figure 4 Specimen Photos
only leaf shape, and given a response format of yes/no.

“Based on only the shape of the leaf, do you think the plant that Christine found was Japanese knotweed?”

Furthermore, they were also asked to give evidence for their choice using only leaf shape.

“Describe how the photographic evidence of leaf shape supports your claim.”

These responses were recorded as written free response answers by the web-based activity. These same prompts with yes/no choices, then free response answers, were repeated again, this time asking participants to base their answers on the flowers of the plant.

“Based only on the flowers, do you think the plant that Christine found was Japanese knotweed?”

“Describe how the photographic evidence of the flowers of the plant supports your claim.”

In these questions participants are asked to give evidence, but the wording does not ask them to compare between species or anything else that would prompt differentiation.

After recording their responses to the second set of questions the participants could press the submit button whenever they finished reviewing their answers, or resolved lingering questions about the activity.

**Participants**

Participants were ten college students and graduate students from the University of Maine. Participation was voluntary and no incentives were offered to participants. Think-alouds were recorded synchronously as the participants completed the activity. No prior knowledge of the activity was presented to the participants before completing the
think-aloud. Qualitative think-aloud data was the only type collected from the study participants.

**Data Collection Method**

I facilitated all participant interviews one at a time for consistency of the think-aloud data. Prior to giving the participants a computer on which to complete the activity I first described the process of engaging in a think-aloud. This process was based on techniques of protocol analysis developed by Ericsson and Simon (1998). Participants were asked to verbalize their thinking throughout the completion of the specified task, in this case the species ID activity. This verbalization did not include any explanation of their thinking or decision-making. Instead participants were instructed to completely focus on the task, while just verbalizing their thoughts. For example, they might have said, “I am looking at the images of the leaves,” without any defense of why they are now looking at the images. The act of verbalizing in this protocol is meant to be non-reactive and the verbalization itself should not influence participant thinking. The goal of using a think-aloud protocol is to record the covert thinking of participants without altering how they are thinking about the task at hand. Participants’ statements were isolated by way of the verbalizations during the think-alouds. These verbalizations were demarcated by natural pauses (Ericsson and Simon, 1998). I informed participants that their think-alouds should include everything, including verbalizing thoughts such as reading prompts aloud. In some instances I demonstrated a brief sentence to clear up issues.

Due to the fact that think-alouds are a novel activity to many people I included a think-aloud warm-up activity in the pre-activity procedure. This activity was the same as the activity used by Shemwell et al., (in preparation). I gave participants a sheet of paper
with the heading: “Think-aloud warm up activity—remember, thinking aloud includes reading aloud and writing aloud. Just keep talking!” This was followed by the following prompt. “In the space below, draw a pair of snowmen. Try to make them look good. In the next question, you will decide which one looks better.” The participants then had to choose which of the two snowmen they liked better and to describe why. This activity served to both familiarize the participants with the process of engaging in a think-aloud and provide a non-threatening context within which to practice and become comfortable with the protocol. When the participants became silent during the warm-up I gave brief talking prompts such as “don’t forget to keep talking aloud.” Furthermore, if the participant had questions about how/what to verbalize I made sure to address these during the warm up activity.

After the participants finished the warm-up activity I gave them an opportunity to ask any lingering questions. If they were comfortable then I directed them to use the computer to begin the activity. During the activity I remained a silent observer unless there were significant gaps in the participants’ utterances. In these instances I gave brief prompts for the participant to keep verbalizing their thoughts. Additionally, if the student had any logistical questions about the survey I briefly answered these (e.g., Participant: “Can I scroll back to the field guide?” Facilitator: “Yes.”)

**Instrument Piloting**

I piloted the survey on a group of post-secondary students as well as one veteran teacher. I choose primarily post-secondary students for the pilot group as a convenience sample and in order to serve as a good analog for the subsequent study. These pilots further served to refine the administration of the think-aloud protocol. Refinements
included clarifying caption language to include fewer distractors. The images used for the leaf shape and flower orientation were also adjusted to make sure that the perceptual features of choice were more clearly observable. The intention was that the features could be discernable in stand-alone images from each species and not to skew the ability of the participants to differentiate between species.

**Analysis Procedure**

There were three main types of codes used in this study. I developed three codes based on the data set. One was for the features that the participants observed. The other two were for the use of contrasts and rebuttal, which provided a window into the differentiation process as well as the application of knowledge gained through differentiation.

I coded think-aloud transcripts for multiple features, where a feature was any physical characteristic of the plants, which could be observed perceptually. However, the features of interest for this study were those that could be contrasted between the two species, and those that were foregrounded by the activity design. A “feature space matrix” was defined based on the frequently used relevant characteristics of both flower structure and leaf shape that were used by participants in their responses. Flower structure included orientation and stiffness. Each of these included two opposing features: up vs. down, and upright vs. droopy. The matrix also had three leaf shape features. The first is the shape of the leaf base. The feature was observed on a scale from flat to round. A second feature, the tip of the leaf, was also observed on a scale from pointy to less pointy. The third feature of leaf shape is the overall shape, which is inclusive of both the base and the tip of the leaf. This was primarily observed as either
“spade” or “heart-shaped.” Each transcript was coded for where and when each part of the feature space matrix was used. Three phases were coded: statements made during field guide observation, statements made during specimen observation/response, and statements made during argumentation.

I coded the transcripts for two specific statement types, contrast statements, and proto-rebuttal statements, the coding of which are discussed in the results section. Additionally, inter-rater reliability was completed for both of these statement types.

I analyzed the think-aloud transcripts with the goal of identifying evidence of learning processes occurring, knowledge generated, ease of its generation, and its usefulness. In order to accomplish this individual transcripts were analyzed as case studies and coded transcripts were also analyzed across participants for the frequency of phenomena occurrence to verify how characteristic these occurrences were. The timing of phenomena occurrence was analyzed for when in the activity they occurred: field guide, specimen observation, or argumentation. The time of emergence of specific ideas during the 10-minute activity was also analyzed, these are discussed in more detail in the results section. Frequency and timing were used to determine the fluidity of processes.
CHAPTER 4
RESULTS

In this chapter I report the data extracted from participant think-alouds, presented within the framework of the study’s research questions. Think-alouds were rich in content, and compiled results of all the think-alouds, as well as case studies of individual think-alouds, are considered.

Features Noticed by Participants

When participants began to interact with the activity they began to engage in the process of “noticing” features. Participants noticed a variety of features of both the flower structures and leaf shape during the activity. I organized features relevant to the study of contrasts between the two alternative features into a feature space matrix (Figure 5). The feature space is organized around features that could be noticed on each plant

<table>
<thead>
<tr>
<th>Flower Structure</th>
<th>Orientation/Stiffness</th>
<th>Tip</th>
<th>Overall Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up/Down</td>
<td>Flat/Round</td>
<td>Pointy/Less Pointy</td>
</tr>
<tr>
<td>&quot;The field guide shows Japanese knotweed flowers growing towards the sky and not towards the ground&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;I am looking at pretty closely is the um where the leaf attaches to the stem of the leaf how the Giant knotweed has more of a heart shaped there whereas the Japanese knotweed has more flat.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;The Japanese knotweed leaf has - for lack of a better description has a very pointy end.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;...looks like a heart where the Japanese one looks like a spade.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5 Feature Space Matrix

and their differences (e.g., the leaf base could be flat or round depending on whether it was Japanese or Giant knotweed). The features in the feature space are primarily those
that were highlighted in the field guide, as discussed in the study design. The field guide highlighted flower orientation (up vs. down) as well as leaf shape (spade vs. heart). The feature space matrix gives examples of ways in which these features were noticed.

Participants often noticed the oppositeness of the flower orientation. However, multiple participants noticed a second feature, which varies from one species to the other: flower density. From the provided photographs, the flowers in the Japanese knotweed appear to be more densely clustered together than the flowers in the Giant knotweed photo. Although the field guide was not intended to support the observation of this contrast the participants often used it. This was an artifact of the images chosen and is not included in the feature space matrix.

The primary feature of the species leaf noticed by the participants was leaf shape. However, there were different ways in which leaf shape was discussed. This included noticing the shape of leaf back, tip, or the overall shape. Examples of these are shown on the feature space matrix. Participants did notice other leaf features, such as the vein structure, but these instances were less common. An example of both a leaf shape and vein feature are given below.

“And uh, so the general shape is sort of heart-shaped, um, and it has the veins that run through the middle.”

I did not include these less common instances, such as the discussion of veins, in the matrix because of their infrequency.
Use of Contrasts

Observing Contrasts

When the participants first looked at the field guide and noticed the features I discussed above, they often mentioned contrasts between features of the two species. Upon reading the caption they noticed that the textual information about the two species was almost the same, and did not contain information that would help them to distinguish between the two species. However, when they looked at the images presented in the field guide they engaged in differentiation. They started making comments about how one species had a characteristic that the other did not. They also discussed one species using language pertaining to the characteristics of the alternative species. In these instances, by using information culled through the differentiation process, participants talked about the species using contrasts, rather than having completely separate language and characteristics with which to discuss each species. Unlike instances where participants did not use contrasts and talked about the characteristics of each species separately without making any mention of the alternate. For example, this participant just described the shape of the Giant knotweed without using any language that pertains to the Japanese knotweed.

“… so the general shape is sort of heart shaped… “

Contrast Maintenance

Participants noticed contrasts between the two species through differentiation when they observed the field guide, but they also used their contrasts beyond the field guide stage of the activity during specimen observation and argumentation. After a participant made an initial contrast statement they often maintained this contrast in the
way they discussed the species features. In the following illustrative example the student repeats the contrast about both leaf and flower characteristics at least once after making their initial contrast statement, even though they are not looking at the field guide any more. Statements 1 and 2 refer to flower orientation and statements 3 and 4 refer to leaf shape characteristics.

(1) *Although those look droopy and those look to be standing up.*

(2) *Because they grow up and they don’t droop and if they dropped they would be giant knotweed. They don’t droop like the giant knotweed.*

(3) *So what I notice about Japanese knotweed is that it has this like flat edge at the base of the leaf, whereas the giant one is rounded.*

(4) *I based it on the base of, the shape of, the base of the leaf. Flat vs. rounded.*

In this example, after the participant used a contrast about a feature once, they continued to use it in their discussion of that species feature.

Participants who maintained contrasts developed contrast dependence knowledge. Contrast dependent knowledge was exhibited when a participant maintained contrasts about either the flower orientation or leaf shape. The use and maintenance of contrasts often coincided with the participant making separate mentions of the feature without using. These mentions were sometimes made as a part of the initial differentiation process or were made within the context of contrasts that the participant already set up. However, once generated the participant’s lens of thinking about the plant feature through a contrast persisted, and became information that was part of how they defined this species and its characteristics. It comprised a key component of their knowledge of the species.
However, participants who noticed contrasts did not always maintain them. In these instances the participants noticed contrasts about one of the features, but then did not recapitulate that statement at any other point in the activity. In the following example, the participant noticed a contrast between the species’ flowers but did not repeat it and instead later used a match-to-target statement to make identification.

(1) Um, it kind of looks like the flowers grow up on the Japanese knotweed? And down on the Giant knotweed?

(2) But the flowers kinda look like they are growing up.

(3) Um, I am going to say they look like they are growing up.

(4) Christine’s knotweed plant appears to have flowers growing upwards similar to the photos of the Japanese knotweed

In the participant’s statement (1) the participant noticed the opposite nature of the flower orientation between the two alternate species (up vs. down). The participant summarized these observations in a contrast statement. Then, in statements 2 through 4 they focused only on the characteristics of one species and did not bring up how they differ. In statement (4) they identified the specimen by using the fact that it grows upward to match it to the target, Giant knotweed. Similarly, participants that did not make any contrast statements used other methods to complete the activity once they moved beyond the field guide. In the following example the student answers the prompt to identify the specimen photos based on their flowers:

“Um, both the flowers that Christine found and the Japanese knotweed flowers were pointed upward.”

This student makes a match to target statement to defend their identification choice,
which allows them to avoid the need to use a contrast all together.

In order to describe the process of contrast statement maintenance and the knowledge it generates I discuss a case study of salient instance of contrast maintenance below.

**Contrast Maintenance: Case Study**

Contrast maintenance was not always observed through the same process or at the same points within the activity. Transcripts were cross-compared to observe different ways in which the knowledge was developed through contrast maintenance. Here, I present one example of how a participant maintained contrasts to generate contrast 
dependence knowledge. One participant began the activity by immediately 
differentiating between both the shape and size characteristics of the species.

“So it looks like the Japanese knotweed doesn’t have sort of those two lobes at the bottom of the leaves....”

In the above statement, they importantly only mentioned one of the species. However, the participant defined the Japanese knotweed exclusively by how it differs from the Giant knotweed. The idea of the Japanese knotweed lacking lobes is persistent throughout the rest of the student’s think-aloud. Before identifying the species based only on shape they generate shape evidence using this same contrast knowledge.

“...has sort of the flatter, um, lobes at the bottom of the leaves.”

They then proposed that the plant is Japanese knotweed. They reasoned with the same contrast statement from before, continuing to maintain this contrast. This statement also serves to indicate that they were thinking about both species during argumentation.
“...the leaves she took pictures of are lacking the lobes at the bottom that the giant knotweed has.”

This student is persistent in their thinking; they never mentioned the field guide or specimen leaves without mentioning the contrast. Their repetition and re-use of the contrasts, such as in the example above, shows that the participant frequently thought about the feature using contrast information, and that a key component of their knowledge about the feature was in the form of how it was different from an alternate. Another instance of contrast maintenance leading to the development of contrast dependent knowledge is shown in Figure 6, where the participant repeated contrasts about flower orientation. In order to determine if contrast maintenance, such as the instance described above, was characteristic across participants I coded all transcripts for contrast use.
Given what I noticed above, I coded transcripts for both the presence and maintenance of contrast statements to see if they were used across participants. When thinking about species features, participants sometimes talked about them using contrast statements. I define contrast statements as statements in which a mention of one species references its relationship with an alternate species. Contrast statements were generated through differentiation between the photographs of the two species. Information used in these statements could only be observed from the photographs and were not available in field guide captions. The use of contrast statements is significant because the activity was designed to foreground leaf and flower contrasts between species.
For coding purposes contrast statements were identified by their inclusion of mentions of the alternative species characteristics. Contrasts are defined as contrasts only between species of leaves, and not a leaf and intermediate (e.g., hand, shoe, measurement tool, etc). Furthermore, these contrasts were between comparable features (e.g., leaf tip shape vs. leaf tip shape, flower orientation vs. flower orientation, etc.). They included any leaf feature or any flower feature. A typical example of a contrast statement was, “So it looks like the Japanese knotweed does not have those two lobes at the bottom of the leaves....” In this statement the student does not cite any features of the Japanese knotweed but instead defines it by the Giant knotweed feature (heart-shaped lobes by the stem), which it does not have.

For using contrasts, I coded all statements on each transcript in which a contrast statement was made concerning either shape or flower characteristics. I also coded transcripts for where in the activity the first contrast statement emerged. Then I coded any reprisals of the contrast statements, as well as where they occurred (e.g., during field guide observation vs. specimen observation). In addition, I coded all mentions of either flower orientation or leaf shape made by participants without using contrasts.

A second researcher and I completed inter-rater reliability for contrast statement identification and distribution. The second researcher demarcated what they believed were contrast statements and whether they occurred within utterances about the field guide, specimen, or written argument. The second researcher coded a practice transcript and then four participant transcripts. Agreement for the four transcripts was 85% or greater than (Appendix A).
Frequency of Contrast Use

Participants frequently discussed or defined one species in terms of its relationship to the alternative species. Figure 7 shows the frequency of contrast use by each participant, and when in the activity they made contrast statements. There were only two think-alouds in which the participants did not use any contrasts. In five out of eight of the instances of contrast use the participants made their first contrast statement during field guide observation. The remaining three participants used contrasts later in the activity, indicating that differentiated between the two species in a way that they were able to access later.

Furthermore, after participants initially made a contrast statement they often repeated the contrast that they used to discuss that species. In six of the eight instances of contrast statement use at least some of the contrast statements were later repeated in the activity. There was one instance of a participant using and maintaining contrasts about leaf or flower. In this scenario the student only repeated contrasts about one of the features they were directed to observe and not another. Five out of ten participants made contrast statements about the leaf and the flowers and then recapitulated these statements later in the think-aloud. As shown in Figure 7 in one of these instances, the participant made contrast statements throughout all three phases of the activity.
For participants who either used, or used and maintained contrasts, this did not mean that they never mentioned species features without contrasts. Figure 8 shows the number of contrasts statements made about flower orientation and leaf shape along with the number of non-contrast statements made about those characteristics by each participant. Some participants observed plant characteristics without contrasts and then made contrast statements. Other participants made contrast statements and then mentioned features without using contrasts. For example, concerning Japanese knotweed, one participant mentioned how “its flowers aren’t droopy.” They then used the fact that the specimen flowers were standing up to identify it as Japanese knotweed. This participant used differentiation to set up the contrast at the beginning and then used
the oppositeness characteristic to ID the specimen without making more full contrast statements.

Figure 8 Contrast and Non Contrast Mentions of Leaf Shape and Flower Orientation Frequency

**Difficulty of Knowledge Construction**

The second research question asked how difficult it was for learners to construct knowledge through differentiation. During the activity participants’ initial process of noticing contrasts was fluid, and this noticing amounted to knowledge that they were able
to both recall and use.

The following excerpt, from a single think-aloud, shows the fluidity with which it was possible to generate these statements in some instances. In this instance the participant immediately made contrast statements (underlined in the excerpt below). This occurred when they first looked at the field guide. The speed at which they made these statements indicates ease. Furthermore, the participant then recapitulated the contrast statements when identifying the unknown specimens. They used both contrast statements and built contrast dependent knowledge.

“Ok, so this is a comparison. *So the knotweed has a flat part here next to the stem whereas this one is more rounded*. These flowers point up and these ones hang down but they are both white and they both have very large leaves. Ok....”

The above statements were made while observing the field guide in less than one minute. After this participant quickly made their initial contrast statements they then observed the specimen photos before reaching the prompt to ID the specimen using each of the feature types. Once they did need to ID the specimen they fluidly resurrected the contrast dependent statements they had used earlier and applied them to each of the types of features. Again, the contrast statements are underlined below.

“*Ok, so the leaves in her pictures have a flatter base near the stem which is more similar to the giant knotweed, or sorry, the Japanese knotweed than the giant knotweed.*”

“And based on the flowers? Again, it is more similar to the pictures of the... Um, ok, so based on the flowers her pictures have the clusters pointing up which is more similar to the Japanese knotweed than the giant knotweed.”
This participant was able to fluidly develop and then access the contrast knowledge about species features that they built.

In this study, participants frequently generated contrast statements through differentiation. As discussed above contrast statements were made by eight out of the ten participants and recapitulated by six. These ideas about contrasts persisted throughout the activity. The use of contrasts by the majority of participants in this small sample provides evidence that using contrasts to think about the species could be accomplished with relatively ease. Participants spent between 40 seconds and 3 minutes looking at the field guide and five of the participants made their first use of contrasts during field guide observations. The process of noticing contrasts occurred fluidly, and these early statements were made quickly without any extensive deliberation or scrutiny of the field guides. Three participants made their first contrast statements within less than 1 minute of field guide observation and five made a contrast statement within the first five minutes of looking at the field guide. Additionally, the entire activity and the noticing and use of contrast knowledge occurred in less than ten minutes.

**Differentiation’s Influence on Reasoning in Argumentation**

Results showed that contrast statements were made frequently, and they were recapitulated. Furthermore, this contrast dependent knowledge was constructed fluidly in many instances. The study looked to see how this knowledge was used by the participants, specifically how it was used during argumentation. Argumentation occurred when students were prompted to provide a written response justifying their ID of the specimen using evidence from the sample leaf, and then a second similar prompt using evidence from the flower. Participants’ use of contrasts contained raw materials for
rebuttal, reasoning that rules out alternative explanations, which they sometimes then used during argumentation to generate rebuttal statements. The use of rebuttal during argumentation is a marker of the knowledge they generated being put to use.

Participants in the study made use of contrasts during the argumentation phase. Rebuttal occurred either preceding the identification statement within it, or following it. For example in the following statement the participant uses rebuttal to support their identification of the specimen as Japanese knotweed.

“Because they grow up and they don't droop and if they dropped they would be Giant knotweed.”

In another instance a student used rebuttal to support their identification of the specimen using leaf characteristics.

“They are probably a little closer to the Japanese knotweed shape. Because they are not really kind of lobate towards the stem.”

Think-alouds were coded for occurrences of rebuttal to determine whether the use of rebuttal as described above was characteristic across participants.

**Rebuttal**

In order to determine how and if rebuttal was used across participants I coded transcripts for rebuttal statements and the species characteristic they utilized. As discussed in design, the activity was structured so the questions that asked for evidence provided a place where rebuttal could occur. Contrast statement use was broken down in its timing: field guide, specimen observation, and argumentation. Evidence of rebuttal, specifically rebuttal within the participants’ written argument, was coded for each transcript. This was one portion of the argumentation phase and did not include when
participants were reasoning about generating their argument. For the purpose of the present study I defined rebuttal as using contrasts to rule out alternative arguments. This is similar to a contrast statement but it is a contrast statements used during written argumentation. It goes beyond just noticing the contrasts and is a statement that uses these contrasts to rule out the alternative. An example of rebuttal during the written argument is as follows:

“Based only on the flowers do you think the plant Christine found was Japanese knotweed. On that I would say yes… …Because they grow up and they don’t droop and if they dropped they would be Giant knotweed.”

In examples of rebuttal the participants used reasoning that ruled out alternative possibilities. I isolated rebuttal statements using the same methodology I used for contrast statements.

A second researcher and I completed inter-rater reliability for the identification of instances of rebuttal within the written argument. A second researcher demarcated what they believed were rebuttal statements. The second researcher coded a practice transcript and then four transcripts. Agreement for the four statements was 100% (Appendix A).

**Rebuttal Frequency During Argumentation**

The inclusion of rebuttal (utilizing contrasts) as part of argumentation by participants occurred frequently. Figure 9 shows the frequency of rebuttal across participants. It shows whether the participant made any contrast statement about either flower orientation or leaf shape, and whether they later made rebuttal statements about either flower or leaf. All arguments that included rebuttal (except for one) utilized the
contrast dependent knowledge, consistence with my rebuttal definition, for the refutation. This statement is shown below.

“Yes, they are Japanese knotweed not Giant knotweed.”

While this student did rebut the alternative, the evidence they used for this only comes from characteristics of the Japanese knotweed and they did not include any reasoning or evidence in support of the rebuttal. Additionally, students who did not identify a species using contrast statements provided less robust responses that did not contain as much evidence as the students who utilized their contrast dependent knowledge to generate their responses.

![Figure 9 Frequency of Rebuttal in Argumentation](image)
In all six of the cases in which contrast statements were repeated rebuttal was used in at least one of the written arguments (Leaf/flower) (figure 9). This is evidence that participants were able to put the knowledge they generated during the think-alouds to use. Students used contrast statements in rebuttal as a part of their reasoning. This reasoning is representative of higher-level thinking, which is desirable and useful in school science.
CHAPTER 5
DISCUSSION AND CONCLUSION

While completing the plant identification activity participants observed contrasts and generated new, useful knowledge. The first section of this discussion focuses on these findings. The second section then explores how differentiation fits with current teaching strategies in school science along with opportunities to expand its utilization in school science. Finally, I conclude by discussing the limitations of this study and future steps to continue this research.

Knowledge Participants Built by Observing Contrasts

Participants learned about species by differentiating between contrasting alternatives. The information that they gathered through the differentiation process allowed them to discuss the species using contrasts. Without having an alternative species to compare to the Japanese knotweed there would not have been a clear opportunity to differentiate. The participants would not have been able to as easily define one species through how it was different from the other. Instead, it is likely that they would have developed two sets of information (one about the Japanese knotweed, and one about Giant knotweed) where their Japanese knotweed information bank would not include any information about Giant knotweed, and vice versa. They would have been building two sets of unified information that fit into their existing knowledge about plant species, a trajectory much more in line with construction.

It is important to highlight the specific type of knowledge that participants generated through the use of differentiation: contrast dependent knowledge. The participants who developed this found a way of thinking about one species, which was
dependent on how it differed from the alternative. This very specific type of knowledge is something that the students were then able to use, as evidenced by the frequent use of rebuttal during argumentation. Two corollary fluid processes occurred that lead students to generate useful knowledge about contrasts (Figure 10). They observed contrasts, these contrasts persisted in their thinking, and they were later useful in argumentation. Mirroring these three phases, participants differentiated between the two species and developed contrast dependent knowledge, which influenced their thinking.

![Figure 10 Processes Occurring during the Activity](image)

Knowledge generated through differentiation is an important part of the development of expert knowledge. Gibson and Gibson (1955) describe the field of contrasting alternatives that experts generate through repeated opportunities for differentiation: the experts can contrast new information they receive with their field of contrasting alternatives. This process then further expands their field of contrasting alternatives. In the present study’s short activity, presenting learners with an alternative to visually compare allowed participants to develop a small fraction of an expert-style field of contrasting alternatives. Participants fluidly generated knowledge of contrasts and a binary field (Giant knotweed vs. Japanese knotweed) of contrasting alternatives. This field, though small in this context, proves useful during argumentation. This is
because as a field, when the learner thinks of one species and its features they also think of the alternative. This structure is good for generating rebuttal because the learner already has an alternative in mind.

The fluid use of contrasts by participants in this study shows that learning through differentiation can play an important role in learning far beyond its role in early child development. This usefulness is highlighted by the presence of rebuttal in student arguments. Through engaging in differentiation learners were able to use rebuttal, which is a difficult process to engage in. Learners favor using confirmation when reasoning about phenomena (Klayman and Ha, 1987); however, the results of this study show that many of the participants used disconfirmation, or rebuttal, when making arguments for the species ID. Explanations using rebuttal are desirable in school science and are included in frameworks (e.g., CERR) designed to help educators teach students to construct scientific explanations (McNeill and Krajcik, 2012). The use of contrasts by participants in this study gave them a way of thinking that makes rebuttal more likely. Having contrast dependent knowledge about the two species created a clear pathway for students to make this a part of their argumentation. When a participant thought about one species the way they characterized it was often linked to the alternate species. This means that during argumentation they were often thinking about both species even when making a single identification. This made the raw material for rebuttal more readily available since they already had an alternative in mind. Activities designed to help students practice CERR skills might benefit from providing students with a differentiation supported activity or information such as that used in this study.

Despite being used by many participants, contrasts were not used by all
participants in this study. Two participants did not use any contrasts, and two more
participants used contrasts but did not maintain these contrasts throughout the activity.
The absence of contrasts from some of the think-alouds does not necessarily mean that
these participants did not notice contrasts. The think-aloud tool has limitations, and does
not capture all participant thinking. There may be thoughts that the participants did not
vocalize, or thinking that occurs so quickly and fluidly that they did not verbalize it.
Alternately, participants may have noticed contrasts but then failed to latch on to them.
They may not have realized that this information was important. For participants that did
use but did not maintain contrasts, their initial contrast use may be so effective that they
were “using” but not vocalizing thoughts about these contrasts as they observed and
identified specimens. For example, some participants used and maintained contrasts
during specimen observation and argumentation, but they did not verbalize any contrast
statements during the field guide observation. The field guide observation was when they
first notice the contrast, but they did not make their first verbalization about it until later.
This speaks to the limitations of the think-aloud. However, within the small sample size
of ten participants, six both used and maintained contrasts. This provides good evidence
that with a larger sample size this phenomena would be prevalent as well. Even with the
tool’s limitations it has provided strong evidence that the development of contrast
dependent knowledge is characteristic of differentiation.

Differentiation in School Science

I began this paper by outlining the persistence of the metaphor of construction,
and the absence of differentiation, in materials that prepare teachers and provide
strategies for teaching school science. Not all constructivist learning is the “metaphorical
construction” and the differentiation processes and contrasts that participants used in this study may indeed occur under the umbrella of constructivism. This is important because precise ideas about what to do under this umbrella are needed. Results of this study show one of the types of knowledge that differentiation produces and its use. This is better than the loose idea of construction, which lacks clarity on the type of knowledge produced and when it is most effective.

As learners observe and interact with new phenomena and information they are likely to employ a variety of learning processes as they incorporate new schema into their conceptual frameworks. Generating and using contrast dependent knowledge might be used by learners to determine categories for new information. However, it is not always a process of building towards a unified idea, or assembling and attaching ideas together. For example, using the framework of this study, a student building their knowledge of new plant species might use their contrast dependent knowledge to make two separate categories of rounded, and not rounded.

Explicit direction on how to leverage differentiation in school science is lacking. The present study’s activity targeted differentiation and not construction, and the learning process of differentiation allowed for the development of contrast dependent knowledge. The differentiation activity used by this study was a research tool designed to help me gain insight into the learning processes occurring; however, results of this study indicate that differentiation shows excellent potential for use in the classroom. Although within the study design this activity did not fit within a broader lesson or unit plan, the structure of juxtaposing information that can be perceptually differentiated could easily be incorporated into classroom resources and curricula. However, as I discuss in my review
of existing resources, there is little to help guide teachers through how to use differentiation in the classroom.

Teachers often learn about key science learning processes and precise teaching strategies to support these processes from educational psychology texts, and resources that distill them. If differentiation is going to be used successfully as a learning process in school science there must be resources that provide teachers with detailed instruction on how students use, and teachers can facilitate, differentiation as a learning process. Educational psychology resources do not provide this, and while literature on contrasting cases primarily focus on students noticing differences in order to build a single unified concept, they do not focus on how differentiation is useful in and of itself (e.g., Shemwell et al., 2015, Schwartz, 2011). The results of this study show that during a short activity (the same length of many contrasting cases studies) learners can generate knowledge comprised of multiple pieces of information about how items differ, rather than being designed to work towards single unified concepts.

Unlike the contrasting cases literature, the present study’s activity was designed to highlight leaf and flower characteristics in the two species allowing learners to observe differences between them. This is similar to Biederman and Schriffrar’s study where giving agricultural workers an opportunity to perceptually differentiate between chick genders using side-by-side images lead them to be able to sex chicks with similar skill to expert chick sexers (1987). Using activities that focus on differentiation as a learning process may help learners to access expert ways of processing information more quickly then using only other processes. Additionally, perceptual processes are cognitively inexpensive (e.g., Kellman and Massey, 2013). Once participants in the present study
noticed contrasts, they frequently used them fluently as a part of their contrast dependent knowledge, further reducing their cognitive load. Continuing use of contrasts may keep increasing student fluency and further reduce cognitive load, which are both important in school science (Kellman and Massey, 2013).

Participants in this study used their small field of alternatives in argumentation. A series of scaffolded differentiated supportive activities likely would quickly broaden this binary field, helping learners generate even more useful knowledge. Considering that this activity took less than ten minutes to complete, you could fit a much more robust differentiation activity into a typical class time of forty to seventy minutes. Alternatively, a short differentiation activity could be worked into a pre-existing class activity to bolster its effectiveness. For example, although he does not use differentiation as fully as the present study in discussing how students notice differences, Calfee (2016) highlighted how comparing force diagrams can support student understanding. This could be incorporated into a physics lab where students needed to draw force diagrams of an experiment, or be a warm up activity at the beginning of a problem set. Additionally, designing differentiation activities to be a part of a broader lesson would provide much needed insight into how they help students with not only learning, but also the transfer of the knowledge gained during these activities.

**Conclusion and Next Steps**

This study took initial steps towards generating a more robust understanding of why it is important to utilize differentiation as a learning process and tool in school science. Results showed that through differentiation participants generate useful knowledge. However, materials with precise strategies for using differentiation in the
classroom do not exist. It is important to develop resources, which teach how to use
differentiation as a mode of instruction in school science. It is also important to know the
key ideas of how this type of learning occurs to inform the design of these resources. In
order to generate robust research-based resources on this topic it is important to continue
research in this field. In order to fill the gap left by the exclusion of differentiation as a
mode of instruction we must also continue to expand communication between
educational psychology experts and the researchers and educational professionals
creating teacher resources.

While results from the 10 adults who provided data for this study show that
differentiation passes the test as a meaningful learning process, the context of this study
in extremely limited. Continuing research on this topic, and this type of targeted
differentiation activity, would benefit from testing similar and expanded differentiation
supported activities in a broad range of STEM content areas and grade bands.
Additionally multiple styles of differentiation learning interventions should be designed
and tested in classrooms. It is particularly important that future studies incorporate the
opportunity to reassess knowledge generated during these differentiation-supported
activities over a longer period of time. This will provide important information about
how well learners retain this contrast dependent knowledge and whether it will continue
to be useful to them during reasoning and argumentation.
REFERENCES


APPENDIX A. IRR RESULTS

Inter-rater reliability (IRR) was completed for both contrast statement coding and for rebuttal statement coding. The results of the IRR are shown below.

<table>
<thead>
<tr>
<th>Rater 1 Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Student 6</td>
</tr>
<tr>
<td>Student 2</td>
</tr>
<tr>
<td>Student 7</td>
</tr>
<tr>
<td>Student 8</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rater 2 Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Student 6</td>
</tr>
<tr>
<td>Student 2</td>
</tr>
<tr>
<td>Student 7</td>
</tr>
<tr>
<td>Student 8</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaf</th>
<th>Field Guide</th>
<th>Specimen</th>
<th>Written Argument</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agreed</td>
<td>Disagreed</td>
<td>Agreed</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flower</th>
<th>Field Guide</th>
<th>Specimen</th>
<th>Written Argument</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agreed</td>
<td>Disagreed</td>
<td>Agreed</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

| Agreed | 23 | Agreement: | 0.85 |
| Disagreed | 4 |         |     |

Table 1 Contrast Statement IRR
<table>
<thead>
<tr>
<th>Rater 1</th>
<th>Argumentation Refutation (Leaf)</th>
<th>Argumentation Refutation (flower)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Participant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student 2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 6</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Student 8</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rater 2</strong></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>Participant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student 2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 6</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Student 9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Student 8</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>Agree</strong></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disagree</strong></td>
<td>0</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2 Refutation IRR
BIOGRAPHY OF THE AUTHOR

Maura Foley was born in 1987 in Schenectady, New York. Upon graduation from Schenectady High School she attended Bates College where she graduated with a Bachelor’s degree in Geology in 2009. Maura then entered the Geology graduate program at The University of Maine and received her Masters in Earth and Climate Science in August 2015. She entered the Masters of Science in Teaching program at the University in the Fall of 2015. She is a candidate for the Master of Science in Teaching degree from The University of Maine in August 2017.