12-4-2019

ALTERNATIVE CONCEPTIONS, INITIAL KNOWLEDGE, AND SELF-EFFICACY OF THE NOVICE AND EXPERT GEOLOGIST REGARDING MINERAL IDENTIFICATION

Amanda Manzanares
manz8075@bears.unco.edu

UNIVERSITY OF NORTHERN COLORADO

Greeley, Colorado

The Graduate School

ALTERNATIVE CONCEPTIONS, INITIAL KNOWLEDGE, AND SELF-EFFICACY OF THE NOVICE AND EXPERT GEOLOGIST REGARDING MINERAL IDENTIFICATION

A Thesis Submitted in Partial Fulfillment
of the Requirement for the Degree of
Master of Arts

Amanda Diane Manzanares

College of Natural and Health Sciences
Department of Earth and Atmospheric Sciences
Geoscience Education

December 2019

This Thesis by: Amanda Diane Manzanares

Entitled: *Alternative Conceptions, Initial Knowledge, and Self-Efficacy of the Novice and Expert Geologist Regarding Mineral Identification.*

has been approved as meeting the requirement for the Degree of Master of Arts in College of Natural and Health Sciences in Department of Earth and Atmospheric Sciences, Geoscience Education

Accepted by the Thesis Committee:

____
Steve Anderson, PhD., Chair

____
Molly Jameson, PhD., Committee Member

____
William Hoyt, PhD., Committee Member

Accepted by the Graduate School

____
Cindy K. Wesley, Ph. D.
Interim Associate Provost and Dean
Graduate School and International Admissions

ABSTRACT

Manzanares, Amanda Diane. *Alternative Conceptions, Initial Knowledge, and Self-Efficacy of the Novice and Expert Geologist Regarding Mineral Identification*. Unpublished Master of Arts thesis, University of Northern Colorado, 2019

Research shows the novice geologist begins an introductory geology course with numerous alternative conceptions about minerals and other geoscience concepts. Students use their prior understanding of these concepts as the basis for future learning. If students' frameworks include alternative conceptions about foundational geoscience concepts, these could hinder their ability to learn more factual and complicated ideas and facts in the future. It takes time to change these alternative conceptions. For this reason, instructors need to understand their students' prior understandings of geoscience concepts at the beginning of the courses to move students to a better understanding of the material. Moreover, the potential impediments to satisfactorily learning the material may also result in lower student confidence levels in the classroom and can affect their academic performances.

The first lab taught to entry level college students is typically a mineral identification lab and it is usually the students' initial introduction to minerals. It is important that this introductory lab provide students with the background necessary to learn material that requires an understanding of minerals. A strong understanding of these concepts will also help students feel confident in their abilities to understand and complete their remaining labs.

In the 2018 spring and fall semesters, data was collected through one-on-one interviews with 15 University of Northern Colorado (UNC) undergraduate students, three UNC graduate teaching assistants and four UNC earth science professors. The purpose of this research is to add to the research that concerns alternative conceptions of the novice earth science student and to better understand and reveal potential differences and similarities of the novice and expert geologist regarding their alternative conceptions, initial knowledge state, and self-efficacy in relation to mineral identification.

My research can help teachers better understand the initial knowledge state of novice geology students so that they can structure their classroom activities to help students move away from alternative conceptions towards a scientifically accurate understanding of the material. Students will then be able to learn more complicated concepts with a correct base knowledge of the subject matter.

ACKNOWLEDGMENTS

I would like to thank Dr. Steve Anderson for his invaluable guidance and support. I am grateful that he nudged me out of my comfort zone to complete my research, because I now have more confidence in myself and my work. I also want to thank Dr. Anderson for his idea to offer volunteers free geological gifts, in the form of rocks, minerals, fossils, and shells and, I want to thank him for his obsidian donations. These gifts replaced the gift cards that I was originally going to use as incentives. All volunteers from novice to expert enjoyed looking through and choosing from the variety of gifts. I am grateful for the papers he gave me to read and for our weekly meetings as these helped my inspiration for my thesis and mold it into a valuable research project. My thesis is that much better from Dr. Anderson's extensive geological and educational expertise.

I would like to thank Dr. Molly Jameson for her guidance and encouragement. I am grateful for her trusting and sharing her library with me as I began to build up my own. While constructing my thesis I found her expertise invaluable. I have learned so much from the classes I took with Dr. Jameson and from our one-on-one meetings and I have grained so much knowledge, compassion, and confidence as both a student and a teacher.

I would like to thank Dr. William Hoyt, as a member on my thesis committee I knew I could rely on Dr. Hoyt to take time to talk to me as I worked through the different stages of my thesis. I also want to thank him for his generous donations of rocks, minerals, and shells that he gave me to help with my thesis. When I asked Dr. Hoyt for donations, he immediately gave me two boxes of shells, rocks, and minerals. I would like to thank Dr. William Hoyt for his edits, advice, and sharing his expertise as I constructed my thesis Dr. Hoyt's encouragement continues to give me confidence in my work.

I would like to thank Dr. Emmett Evanoff for advice, edits, and expertise during the ESCI 600 research course. I would also like to thank Dr. Evanoff for his generous donation of fossils that were used as gifts for the volunteers.

I would like to thank Dr. Julie Sexton for her supervision and assistance and for sharing with me her research and expertise when I began construction of my thesis.

I would like to thank the student and faculty members of The Science Education Research Group (SERG) for their support and feedback concerning my thesis. That group formed under the auspices of the Mathematics and Science Teaching Center (MAST) and met in their facilities. Thanks to Assistant Dean and Director of MAST Dr. David Slykhuis, Ph. D.

I would like to thank the faculty and staff of the Department of Earth and Atmospheric Sciences, my friends, and fellow graduate students. I have enjoyed laughing and learning with everyone. It was always comforting to be surrounded by a great community that made my time at the University of Northern Colorado all the richer.

I would like to thank my family who makes every day of my life better and whom have given me the support and courage to conquer my dreams.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION TO THE STUDY

Statement of Problem

A mineral identification lab is typically among the first labs taught to entry level college students and it serves as their initial introduction to minerals. It is important that this introductory lab provide students with a strong foundation, as many geologic topics rely on a firm understanding of these concepts learned in the introductory lab. Previous research indicates that the novice geologist begins an introductory geology course with alternative conceptions that may hinder the student's ability to learn the material (e.g., Anderson & Libarkin, 2016; Cheek, 2010; Dahl et al., 2005; Francek, 2013; King, 2010; Monteiro et al., 2012). Alternative conceptions have also been defined as misconceptions, (e.g., Francek, 2013; King, 2010), alternate conceptions (e.g., Francek, 2013; Schoon, 1992) and conceptual prisms (e.g., Francek, 2013; Kusnick, 2002).

Instructors may be unaware of their students' alternative conceptions and may overestimate their students' initial knowledge pertaining to minerals, consequently the instructors may not address the information that they feel students should already know (Anderson & Libarkin, 2016; Libarkin & Anderson, 2005; Sadler, 1998). This may mean students will complete the lab but may not understand the material. Instructors should learn how to recognize and best correct these alternative conceptions (e.g., Anderson & Libarkin, 2016). It is possible that if these alternate conceptions are not addressed, students will continue to believe false information and will not understand why their answers are incorrect (Monteiro et al., 2012; Sadler, 1998).

Research shows that students' confidence levels in the classroom can affect their academic performance (Hulleman & Harackiewicz, 2009; Monteiro et al., 2012; Zimmerman, 2000). Students may be overwhelmed with the idea of learning to identify minerals, and their lack of confidence may hinder learning. However, too much confidence can also have a negative impact on a student's academic potential in the classroom (Hulleman & Harackiewicz, 2009). Overconfident students may not pay attention in class, because they believe they already know the material and consequently perform poorly in lab.

There is previous research by Anderson & Libarkin, (2016); Libarkin & Anderson, (2005); and Monteiro et al., (2012) that concerns alternative conceptions of the novice earth science student, but it is incomplete and does not fully reveal the initial knowledge state of these students. The purpose of my research is to add to this and other relevant research by giving further insight into the alternative conceptions held by the novice earth science student. My research will provide teachers with information about the efficacy of novice geologists and an awareness of a student's background knowledge. Professors can use this study to structure their classroom activities and help move their students away from their alternative conceptions and towards correct scientific concepts. Students will then be able to learn more complicated concepts with a correct base knowledge of the subject matter.

My research questions for this project include:

Q1 How does a volunteer's prior knowledge affect their answers?

Q2 Are there incorrect ideas that appear in more than one interview?

Q3 Do experts and novices respond differently to the interview questions? If yes, how do they respond differently? (e.g., terminology, use of analogies.)

Q4 Is there a relationship between confidence levels and how accurately volunteers answer questions?

Significance of Problem

The purpose of this project is to add to the relevant research that concerns alternative conceptions of the novice earth science student and to better understand and reveal potential differences and similarities of the novice and expert geologist regarding their alternative conceptions, initial knowledge state, and self-efficacy relating to mineral identification. To understand and correct alternative conceptions is significant, because incorrect conceptions can impede a student's ability to learn new concepts (e.g., Anderson & Libarkin, 2016; Libarkin & Anderson, 2005; Monteiro et al., 2012; Sadler, 1998). If students' knowledge about geological concepts are incorrect, any new knowledge they attempt to add will not have a strong foundation on which to build (Hill et al., 2008; Kusnick, 2002; Prawat, 1992; Sewell, 2002).

For instance, a student who first learns to identify a piece of orthoclase that is a length of 6 centimeters may not recognize an orthoclase if it is larger or smaller than what he/she originally studied, e.g., if asked to identify the minerals in a sample of granite the student may not recognize the orthoclase that is now 1 cementer in length. Sadler (1998) states that it can also take a long time to break down these alternative conceptions if a student has believed them for years. However, if teachers identify the common alternative conceptions, they can more effectively teach the correct concepts and not reinforce any common alternative conceptions. Informed instructors can best determine how to shift students towards a more scientifically accurate understanding of these concepts (e.g., Anderson & Libarkin, 2016).

Past studies (e.g., Sadler, 1998) confirm the importance of instructors' awareness of their students' prior knowledge. Blooms Taxonomy emphasizes this idea that there are stages to how students learn (Krathwohl, 2002). Novices must first know and understand mineral concepts before they can analyze and interpret these facts in depth later as experts. To misunderstand these concepts can impede students from understanding and interpreting other complicated ideas (Krathwohl, 2002).

Furthermore, teachers may expect students to have a certain background knowledge about minerals when they begin an introductory college geology course. As a result, teachers may offer only a quick review of the material or not cover the information that they feel students should already know. Consequently, if a student has not built up the appropriate knowledge, he/she may become confused. The student may not understand the lab and could then struggle with the lab material.

However, if teachers have an awareness of the average introductory college students' knowledge and alternative conceptions relating to minerals, then teachers can design a mineral lab that addresses these gaps in their students' knowledge (Anderson & Libarkin, 2016; Libarkin & Anderson, 2005; Monteiro et al., 2012; Sadler, 1998). Students will then be able to learn more complicated material with a correct base knowledge of the subject matter (Krathwohl, 2002).

Like Blooms Taxonomy, Piaget's theory that concerns concrete and abstract thinking can be used to show the development from a novice to an expert geologist. Piaget describes children as concrete thinkers; they take things literally and it is why you can make them believe you have disappeared when you have put your hands in front of your face (Ausubel, 1964; Ding & Li, 2014; Krathwohl, 2002). Novice geologists think about minerals and mineral processes in a more literal and simplified way and therefore they may tend to focus on how minerals look and feel.

However, as people mature, we acquire more knowledge and we can think more abstractly. I relate this to how an expert geologist thinks about minerals concepts. An expert has more knowledge about minerals and so when asked a question about how minerals may react when placed in the sunlight for a year an expert may talk about the mineral's chemical bonds, while a novice may only discuss changes in color (Ausubel, 1964; Ding & Li, 2014).

A student's cognitive load is another factor that can influence a student's performance in lab. Descibed by De Jong (2010), cognitive load theory's core idea is a learner's working memory has a limited amount of space. A potential consequence of overloading students working memory is that the students are not focused enough on the actual lab to learn how to identify minerals properly or learn valuable geological concepts (e.g. De Jong, 2010; Paas et al., 2010). It is important that instructors are aware that their students have limited space for working memory. Once aware of this, instructors can then create solutions to reduce students' cognitive load and provide opportunities for them to learn the geological concepts they will need to complete future assignments.

Previous research cites that a student's self-efficacy affects his or her academic performance (e.g., Zimmerman, 2000). Students may lack confidence in their abilities to correctly identify minerals and understand important geological processes. This lack of confidence can make it harder for them to learn the material and complete the lab.

Conversely, if students are overconfident in their abilities this can have a negative impact on their performance in the classroom. Students may be disruptive or not pay attention, because they think they already know the material. Teachers should be aware of students' confidence levels and help them feel comfortable in the classroom and to impress upon the students that there is important material to be learned (Hulleman & Harackiewicz, 2009; Monteiro et al., 2012; Zimmerman, 2000). My research will provide instructors with information about the efficacy of novice geologists and they can use this information to develop a mineral lab that promotes a meaningful learning environment.

CHAPTER II

REVIEW OF LITERATURE

Kindergarten through baccalaureate students have a variety of alternative conceptions regarding geoscience concepts. For example research has found alternative conceptions that concerns geological time (e.g., Cheek, 2010; King, 2010; Libarkin et al., 2007), plate tectonics (e.g., Dahl et al., 2005; Francek, 2013), mineral and rock identification (e.g., Kusnick, 2002; Monteiro et al., 2012), rivers (e.g., Francek, 2013; Sexton, 2012) volcanoes (e.g., Anderson & Libarkin, 2016; Cheek, 2010; King, 2010), and earthquakes (e.g., Anderson & Libarkin, 2016; Schoon, 1992). Research by Monteiro et al. (2012) found that many Portuguese high school students were misinformed about what is a mineral. Many students believed that for a crystal to be a mineral, the crystal had to have a perfect form with planer faces. Students also had difficulty understanding that sea ice is a mineral, because as a solid sea ice meets the requirements for a substance to be a mineral. However, because sea ice forms from water, a liquid, the students struggled to identify sea ice as a mineral (Monteiro et al., 2012).

It is key that instructors recognize that students do not begin science classes as blank slates (e.g., Anderson & Libarkin, 2016; Cheek, 2010; Leinhardt et al., 2003; Kusnick, 2002; Libarkin & Anderson, 2005; Libarkin et al., 2007; Schoon, 1992). Through life experiences, media and schooling, students walk into a geoscience classroom with their own understanding of geoscience concepts, whether these notions are correct or not. To determine how to best correct these alternative conceptions instructors must account for how students learn and gain knowledge.

Sewell (2002) describes the constructivist learning theory. It asserts that students do not just absorb knowledge but build off their prior knowledge concerning a subject. If their knowledge about geological concepts are incorrect, any new knowledge they attempt to add will not have a strong foundation on which to build (Hill et al., 2008; Kusnick, 2002; Prawat, 1992; Sewell, 2002).

Cognitive psychology, like constructivism, views learners as active participants in their learning environment (Bruning et al., 1995; Schwartz & Goldstone, 2016). Schemata or schema are constructs of cognitive psychology and describe how learners construct memory and process information. Learners have a mental framework to which they continue to build and connect their memory and knowledge. If students' frameworks for mineral concepts are full of alternative conceptions, teachers need to be equipped with the skills to correct any alternative conceptions held by their students and replace them with correct concepts. (e.g., Anderson & Libarkin, 2016; Darling-Hammond, 2000). This way their students will have strong and correct frames of reference when they complete their current and any future geoscience courses (e.g., Bruning et al., 1995; Schwartz & Goldstone, 2016).

As discussed in Leinhardt et al. (2003) to become experts students need to build up their knowledge. A focus of their research is the influence of museums in a child's education and emphasizes that students gain knowlegde and build and/or add to their islands of knowledge outside of the classroom. Like the idea that students create schema, the article describes that as people add to their knowledge about a subject they build an island of expertise through experances in and outside of the classroom. This gained knowledge can have an effect on how big and accurate are these islands of expertise (Leinhardt et al., 2003).

Blooms Taxonomy is a classification system that promotes the idea that there are stages to a student's learning and development (Krathwohl, 2002). The lowest levels show that a student must first learn and understand the concepts they are being taught before they are able to analyze, explain and critically think about these concepts (Krathwohl, 2002). If students do not understand the foundational concepts pertaining to minerals and mineral processes then they will find it difficult to relate, explain, and test these and more complicated concepts in lab.

Piaget's theory of concrete to abstract thinking descibes how as children people think and learn about their world through empirical experiances and as people grow and gain more knowledge they can think about problems and the world in more abstract ways (Ausubel, 1964; Ding & Li, 2014). There are stages that students go though as they learn new subjects and although some may move through these stages faster or slower then others all students take steps as they transition from concrete to abstract thinkers. Ausubel (1964) describes that some of the first steps students need to accomplish is to understand the topic's vocabulary and then use those terms as they explain and relate to concrete ideas. As the student learns he/she can use this base knowledge to understand more complicated and abstract ideas that relate to the subject.

Another factor that instructors should consider is their students' cognitive loads. The fundemental idea behind cognitive load theory is that the amount of space in a learner's working memory is limited (De Jong, 2010). If students are confronted in class with new and/or contradictory information about what they understand in regards to geoscience concepts, they may be overwhelmed as their cognitive load is filled with this new information (De Jong, 2010; Paas et al., 2010). Instructors can work with their students to help determine how to replace alternative conceptions with correct concepts without overwhelming their students.

It is important to note that even if students retain or gain new alternative conceptions in class, they may be working toward a better understanding of the material. Research by Libarkin & Anderson (2005) found that between pre-and post- geoscience assessment tests, certain students shifted from one wrong answer to another. This can still mark progress as students begin to understand geoscience concepts better (e.g., Sadler, 1998).

Furthermore, Sadler (1998) states that it can take a long time to break down these alternative conceptions if a student has believed them for years. Consequently, teachers should know of common alternative conceptions, so that they can design classroom interventions that avoid the reinforcement of these incorrect ideas and provide their students with a correct foundation of geological concepts (e.g., Anderson & Libarkin, 2016; King, 2010; Monteiro et al., 2012; Sexton, 2012).

Forcino (2013) states that students may outgrow certain alternative concepts that can arise from their imagination or supernatural beliefs. However, this does not always happen. Also, students may outgrow certain incorrect ideas but retain others. Therefore, instructors should identify and understand their students' alternative conceptions in order to help students replace their misinformation with correct geoscience concepts (e.g., Cheek, 2010; Kusnick, 2002; Sewell, 2002).

CHAPTER III

METHODOLOGY

Surveys

Data for my research was collected through 22 interviews that occurred in the Spring and Fall semesters of 2018. In order to develop an interview protocol, I wrote a 15 to 20-minute survey during the 2017 fall semester. Seven UNC student volunteers were surveyed, a mix of science and non-science majors. After completion of the survey, students were compensated with free doughnuts. These surveys were trials and the answers to the surveys were not recorded. I did not record students' names, nor their bear numbers, and all surveys were destroyed. All students that were surveyed had not taken a geology class at UNC.

The fall 2017 survey had two parts. Part I of the survey was to acquire background information on the students. Part II of the survey was to ascertain what students knew and understood in relation to minerals. Six samples, three minerals and three everyday objects, were placed in front of student volunteers (Figure 3.1). The volunteers were asked to answer specific questions that related to their understanding about minerals, such as, what do they think a mineral is made of, what is the difference between these samples, what would happen if a mineral was placed in water for a year? The students were also asked to choose and draw one of the samples that they believed to be a mineral. I presented my preliminary findings to the UNC Science Education

Research Group (SERG), an association of science researchers, science educators, and students. I received feedback and suggestions from the group for going forward with my research.

Figure 3.1 Shown are the six samples used in the survey. From left to right: muscovite, a stick, kaolinite, quartz, a glass plate, a nail.

I used the information from these surveys to complete an interview protocol that was approved by the Institutional Review Board (Appendix A). After receiving permission from the Institutional Review Board, I began my interviews.

Interviews

In the 2018 spring and fall semesters I interviewed 15 UNC undergraduate students that have not taken a college level geology course at UNC. Both science and non-science majors were questioned. Three UNC graduate teaching assistants and four UNC earth science professors were also interviewed. For my research the undergraduate students are considered novices and both graduate students and professors are considered experts.

The interviews were one-on-one and took approximately 40 minutes to an hour each to complete. All participants were volunteers and received compensation at the completion of the interview, e.g. two free samples of fossils, rocks, minerals, shells, or coral. These samples were donated by faculty in the Earth and Atmospheric Sciences Department.

The volunteers were asked to verbally answer questions and to write out their answers. The interviews were videotaped in a manner that protected their identity. When I reviewed the interviews, I listened for key words that provided me with valuable data for my thesis research. After each interview the qualitative and quantitative data were analyzed to allow slight modifications to the interview protocol to ensure the capture of the best and most comparable data in the next interview session.

Volunteers were first asked to answer background questions, e.g., about their age, gender identity, and science background. I used this information to ascertain their level of expertise and determine if there are any correlations between the volunteers' background information and their responses to mineral identification.

For certain questions the volunteers were presented with multiple mineral samples. For example, the volunteers were asked to describe the differences they saw between five clear minerals (gypsum, plagioclase, muscovite, quartz, and halite) that have distinctive fractures or cleavage (Figure 3.2).

For another question, the same potassium feldspar sample was placed in front of the volunteers (Figure 3.3). I requested that the participants draw and write out their observations about this mineral. Other questions did not require samples. Instead, the participants were asked to think about the certain properties of minerals, e.g., what would happen if a mineral was set out in the sun for a year? The 2018 spring and fall semesters' interview questions were selected and modified from trial survey questions completed in the 2017 fall semester (Appendix A).

Figure 3.2. Shown are the five samples that the volunteers were asked to describe for question 19. From left to right: gypsum, plagioclase, muscovite, quartz, and halite.

Figure 3.3. Shown is the potassium feldspar sample that volunteers were asked to draw for question 13.

Interview responses and observational notes provided qualitative and quantitative data that was coded based off any developing themes and concepts. Due to discrepancies, after the completion of 24 interviews I decided not to include Interviews 1 and 3. Interview 1 was a trial interview, intended to help me work out any issues that I foresaw with the interview process, e.g., camera placement and transitions between questions.

Interview 1 was never intended to be included in the results. Interview 3 is not included due to inconstancies with this interview that may have affected some/all answers. Due to unforeseen circumstance the interview did not take place in the same interview room as the other interviews. Furthermore, for question 16 concerning dating minerals, a different muscovite sample was accidentally used and so differed from the other 23 interviews.

Reliability, Software, and Equipment

A Sony HDRSR7 HD video camcorder was provided by Dr. Steve Anderson and was used for my research. Interviews were implemented and recorded during the 2018 spring and fall semesters.

To aid in the organization and analysis of the qualitative and quantitative data, I utilized IBM-SPSS and Microsoft Word. I used IBM-SPSS to test if there is a significant difference between novices and experts and the number of alternative conceptions reported by each group. The seven experts were paired with seven novices of the same gender identity and grew up in the same or similar environment, e.g., two females, grew up in a suburb. Due to the small sample size I could not match all experts with novices with the same background. I therefore matched the experts with novices of similar environments, e.g., an expert from a small town was matched with a novice from a suburb, not a city.

To recognize alternative conceptions that could be common in an introductory geology lab, I searched for incorrect ideas that appear in more than one interview. I utilized Microsoft Word to search and count how many times certain terms or phrases such as, “layers” and “I don’t know”, appear in each interview. Through the analysis of the 22 transcripts I looked for how a volunteer’s prior knowledge can affect his/her answers, e.g., do novices list non-minerals as minerals and are there incorrect ideas that appear in more than one interview? Novice and expert answers were analyzed and compared to determine if they respond differently to the interview questions? If yes, how do they respond differently, e.g., terminology and use of analogies?

Reliability was assessed by Dr. Steve Anderson. Dr. Anderson's initial analysis of Interview 2 provided us with a reliability of ~50%. I believe this was because I had not developed a solid and consistent way to identify the volunteer's confidence levels, use of past knowledge, and interest in minerals. Since then, I have developed a more reliable rubric for myself and others to follow, e.g., when a volunteer uses their past knowledge the transcription is highlighted orange. All 22 transcriptions were color coded based off this new rubric. Dr. Anderson re-coded three out of 22 transcriptions, about 14% of the total transcriptions. The interviews that were re-coded by Dr. Anderson were Interview 2, an undergraduate student, Interview 19, a graduate student, and Interview 24, a professor. The results from the reliability assessment are strong at 72.5 %, 76.1%, and 83.5%. My assessment of Interview 2, Interview 19, and Interview 24 can be found in Appendix B.

CHAPTER IV

RESULTS

Initial Knowledge State

Constructivism and cognitive psychology explain how people build and add to their knowledge as they learn and explain the world through the knowledge that they have gained (e.g., Bruning et al., 1995; Sewell, 2002). This is apparent as both novice and expert volunteers used their prior knowledge to answer interview questions. An example of this is when a novice geologist used his/her background in geology and from other sciences, e.g., chemistry and/or biology, to relate to minerals. Interview 13 described how all minerals contain and are affected by carbon,

> Well, I mean they are made up of atoms, definitely, but ah…ah, um, well because, I mean, I took in biology and chemistry they have you learn the periodic table… and you learn about all the stuff and you learn about how carbon is the building block of everything. So, it makes sense that they would be made up of elements from the periodic table, because I mean if carbon builds everything then of course it is going to have some effect on all of the, like on all minerals. Interview 13.

Moreover, Interview 6's answer to question 14, whether the sample of kaolinite is a mineral why or why not, explained that the sample looks like a rock, because of the sedimentary layers that he sees.

Life experiences outside of the classroom also effected how volunteers answered interview questions. In Interview 10, the volunteer explained that she thought a mineral may freckle because skin can freckle when exposed to sunlight.

> Like if you are baking it in the sun, kind of like how it, when like in the summer you are in the sun a lot, you get more freckly, like some people do. I feel like if you put a certain mineral in the sun for a long time it would freckle, like some things on the inside would be pulled to the surface. Interview 10.

Interview 4 continuously brought up the trips she has taken with her father and used the information she gained from those trips to answer questions, such as number 13. She explained that the smooth surfaces of the mineral (the cleavage) are formed, because the mineral lay in a riverbed and the smooth sides are where water ran over the sample and smoothed out the mineral.

> So, if it's like in a river than like over time, the rock would sit and I know you know this, but the water would like smooth out the rock and that is how you get the shiny, the shiny I don't know the river rocks. Cause like, I don't know if there's any unaffected areas that it would just mean that it was deeper in the bed rock, than the exposed area. I mean there could be other, one but I'm just, specifically like that, that's what my dad and I would go into like rivers and find like a bunch of quartz and we like see the difference like the effect of nature over time and how that effected the texture and the shape of the rock. Interview 4.

Additionally, Interview 13 believed that he could date rocks by color, because he learned on a kayaking trip that the older rock layers on the bottom of the canyon where darker and the color of the rock had something to do with its age.

It is also common for the novice volunteers to use their knowledge about everyday items or scientific process to relate to the minerals through analogies. Interview 4 related most of the samples for question 19 to food and everyday objects like tree bark.

> Okay. Differences, this one (mica) is very flaky, like thin and flaky. In terms of its physical texture, I feel like I could just like flake one of these off and eat it like a croissant. This one is very similar (gypsum) but it is more like tree bark, so it would take a little more effort at least from appearance, you would have to pull it off, this (mica) would just flake off. And these you would definitely have to break into somehow (quartz, plagioclase, halite). Like there's no, I mean this one (plagioclase) you could potentially, this is more like a block of cheese, you would have to

> work at it. Umm, this one (halite) looks like a little cube of condensed cilantro that you would just through in a pot of water, so I mean, I don't know if that's the differences. Interview 4.

Interview 10 also said that the gypsum sample in question 19 looked like tree bark and related the other samples to food. She also described the layers she saw in the gypsum as similar to folding a piece of paper.

> This one (gypsum) looks like a piece of bark broken off a mineral tree. These two look very similar (quartz and halite), this ones (halite) more, looks like an ice cube. This one (quartz) looks like a dirty ice cube…This one (gypsum) has a lot of lines on it, which could either indicate a lot of folding or other things acting on it…like if you fold a piece of paper a bunch of times, like it looks like on this side (side view) is where you would see all the different folds. Interview 10.

These examples indicate that students want to relate what they see and what they are learning to something that they already know. To emphasize this point, when asked how many minerals the volunteers believe that they could learn to identify in two hours, Interview 11 is quoted as saying,

> I'm not sure, if I were to guess, 4 really well, because I could connect each mineral's certain characteristics, with something else that I know, to help me remember it. And it is also color, shape, weight, what texture it has, like those all would help me learn it. Interview 11.

It is also common for a novice to answer an interview question based off their answer to a prior question. As an example, Interview 15 described kaolinite as chalky and not smooth or shiny like the previous sample of potassium feldspar. When asked what that means to her, she replied that kaolinite was probably not a mineral based off this comparison. Interview 15 demonstrates how readily novices latch on to their beliefs and ideas, whether they are accurate or not, to understand and explain new concepts.

As with a novice an expert uses his or her past knowledge to answer interview questions. This is apparent for question number 11 "What is something that you understand to be true about minerals?" All seven experts answered this question by describing a mineral's properties, that it must be solid, inorganic, has a crystalline structure, etc.

> I was writing down almost the definition of a mineral. Interview 23.

> Well, I know that they are solid, crystalline, inorganic, definite chemical structure. Interview 19.

Experts' answers to question 11 show that they have learned and taken classes about minerals, as does a comparison of novice and expert answers for question 10 (Table 4.1).

Table 4.1 Novices' Answers to Question 10.

Interview Number	Total Number of Minerals Listed	Number of Minerals Correctly Named
2	0	0
4	3	1
5	0	0
6	6	1
7	4	3
8	5	3
9	5	5
10	0	0
11	3	0
12	1	1
13	5	4
14	3	1
15	0	0
16	4	1
18	8	5

Question 10 asked volunteers to list as many minerals as they could name. Table 4.1 shows the answers for the 15 novice undergraduate students. The first column gives the interview number and the second column shows how many mineral names the volunteers listed. The total number of minerals listed does not exceed 10 as its range is from 0 to 8 and the average is ~3. The third column shows the number of minerals the volunteers correctly named. The range for this column is 0 to 5 with an average ~2. While, the range of minerals listed and correctly named by experts is 22 to 100 with an average of about 49. However, for this question I asked the experts to write down how many minerals they believe they could name, instead of a list of minerals, as we could have spent the entire interview time on this one question while they contemplated mineral names. I therefore assumed that the professors and the graduate students would have accurately named the number of minerals they indicated.

Both novices and experts have prior knowledge about minerals, however their answers to questions 10 and 11 make clear that the experts have learned about minerals and have more knowledge regarding minerals. What is also evident by these answers and other answers given by novices is students already have an idea about what minerals are and maybe even feel they can name and/or identify certain minerals.

Common Themes and Alternative Conceptions

Monteiro et al. (2012) found that high school students who took part in their study believed that for something to be a mineral it had to be shiny and have the expected crystal form with planer faces. My research confirms that both novices and experts use terms such as crystal, pure crystal, and perfect crystal to describe certain samples, such as the quartz sample used for question 19 (Figure 4.1). The experts recognized this sample as a great sample of a quartz mineral with planer faces.

This one has nice crystal faces (quartz), it grew that way. Interview 22.

However, the experts also know that not all minerals have planer faces and can recognize and identify minerals that lack planer faces. Whereas, multiple novices took this quartz sample as an example of what a mineral should look like.

> So, I feel that this is a more pure form of a similar substance (indicates quartz) … And then I feel that at some point this (halite) could have had a point to it. That could have been similar to that structure (meaning quartz) … Yeah, this is (quartz), if I were, if anyone were to image just like, imagine a crystal this is what it would look like. Interview 2.

Interview 6 described the sample as having the basic crystal form. This idea of a pure form could result in alternative conceptions as expressed by Interview 11 who descibed the sample of gypsum in question 19 as having more rock than crystal in it and so it is not a pure crystal (Figure 4.2).

Figure 4.1 Shown is the quarts sample for question 19.

Figure 4.2 Shown is the gypsum sample for question 19.

My interview results agree with Monteiro et al. (2012) findings that alternative conceptions about the shape and look of the mineral can also influence a novice's view about the sample. Interview 4 described how the kaolinite (Figure 4.3) for question 14 was not a mineral as minerals must be desirable and shiny like a diamond or a rose quartz.

> No this is a rock because it doesn't have that shiny quality to it. No, it also has its own distinct texture on it, like you can feel the difference. Like the I guess if you broke it, it might have something inside, but at least from the exterior I'm think that this is just a rock. Right because minerals have some kind of like okay, now I'm remembering, I think it's, because minerals have some kind of desirability to them, like this is shiny (picks up quartz), so somebody could be like, oh that has value like a diamond. Like people see that and they are like oh it's shiny and has value. Interview 4.

Figure 4.3. Shown is the kaolinite sample for question 14.

Some novice volunteers concluded that the kaolinite (Figure 4.3) was not a mineral because they believe minerals should have a certian density and/or feel and look a certain way.

> It's kind of chalky. It is not smooth and shiny like the last one…It's probably not then…Well, it doesn't really share any features with the last one. It's a lot lighter, it's all over my fingers. It just doesn't feel the same. Interview 15.

> I want to say no. the reason for that being is it's very light, if it was a real mineral it would be denser. And there's also a little bit of damage that shows its kind of powdery. It also feels powdery as well…I would say, I would say so. I think weight is a big part of what can be used to identify a mineral…General knowledge of weight and testing, like how can you tell if something it buoyant or not, that's kind of what I am basing this off of… How do I explain this? I would say if it is a pure mineral, that the atoms making up are heavy and they would want to sink, b/c for the most part rocks, granite all that sinks, because of the atoms that it's made of,

> more buoyant materials are kind of reformed or remade of minerals, but not exactly in a pure state. Interview 11

Other interviews, e.g., (Interviews 2 and 5) felt that the feldspar in question 19 stood out from the rest of the samples (Figure 4.4). Due to it's size, shape, weight and/or apparent lack of layers it was described as a rock by both volunteers. Many novice volunteers also expressed that certain minerals they saw were man-made or cut into their current forms, e.g., halite and quartz were cut into their current shapes since the novices did not feel the minerals could form that way naturally. Interview 5 explained that you could see evidence of layering and cut marks on all the samples for question 19.

Figure 4.4. Shown is the feldspar sample for question 19.

The perthitic texture in the potasium feldspar sample for question 13 stood out to both expert and novice (Figures 4.5). When presented with the potasium feldspar for question 13, one of the first characteristics that all volunteers noted, but not usually accurately identified, was the perthitic texture. A common alternative conception held by the novices was that this texture was due to layering. Interview 10 described that the sample formed from burial as layers of sediment stacked on top of one another and though heat and pressure. Her answer demonstrates that she had some correct prior knowlegde on the formation of sedimentary rocks, but this prior knowledge was incorrectly used in this circumstance.

Figure 4.5. Shown is the perthitic texture of the feldspar sample for question 13.

My research implies that a common alternative conception believed by novices is that minerals formed from layering or stacking of sediment. When novices saw lines in a mineral or when they looked at minerals like mica or gypsum they tended to point out the layers. Some novices believed that they could use these layers to date a mineral. For example, Interview 8 explained that the mica is the youngest out of the four samples used for qustion 16, because it does not have enough layers, whereas Inteview 9 described hematite as the oldest sample due to the lack of layers (Figure 4.6). This common knowledge of bedding and layering even threw off experts. Interview 21 felt the kaolinite was a sedimentary rock, one reason being she felt she saw lamination beds.

> It kind of looks like it might have bedding like finer lamination layers in it too, potentially. Interview 21.

Another alternative conception displayed by multiple novice volunteers was that with time minerals can change into one another or they are related to each other.

> But these two are definitely layered (gypsum and mica … So that gives me the suspicion that they are related somehow… I think as far as where they are found as well as how they got to where they are found. Interview 2.

Figure 4.6. Shown are the four samples used for question 16. From left to right: dolomite, muscovite, hematite, and chalcopyrite.

Another alternative conception displayed by multiple novice volunteers was that with time minerals can change into one another or they are related to each other.

> But these two are definitely layered (gypsum and mica) …So that gives me the suspicion that they are related somehow… I think as far as where they are found as well as how they got to where they are found. Interview 2.

Interview 10 placed the 5 samples for question 19 (Figure 4.7) in a row: quartz, halite, gypsum, feldspar and muscovite, and explained that due to color, their formation could be a progression. She believed it is possible that formation begins with quartz and concluded that with time each mineral changed until muscovite was formed.

Moreover, for question 19, volunteers often grouped halite and quartz together due to their geometric shape, clarity and color. The muscovite and gypsum were also grouped due to their shape, appearance of layers, and clarity and could therefore, be assumed that with time one mineral might change into the other (Figure 4.7).

> But, I'm not sure that could just be my organizational mind going to work here. But these two have a very similar shine to them as well (mica and

> gypsum). And these two have the structure that goes along this way (indicates quartz and halite. Showing the flat sides). Verses the lengthwise (indicating the flatness of mica and gypsum). And then I feel that at some point this (halite) could have had a point to it. That could have been similar to that structure (meaning quartz). The only big thing that throughs me off here is that this is a hexagon verses the cube shape. But these two are definitely layered (gypsum and mica) …So that gives me the suspicion that they are related somehow…I think as far as where they are found as well as how they got to where they are found... So, like this would be, part of a much larger whole (touches mica) and if it were to like broken down or something were to have changed there, it would turn into this (the gypsum) if that makes sense? Interview 2.

Another alternative conception expressed by several novice volunteers was that the age of a rock could be determined by fragility, layering, and color. As an example, Interview 8 was unsure if the fragility of the muscovite sample for question 19 meant that it was older or younger but felt it had something to do with age (Figure 4.7).

> Something is happening, maybe its older, or new, maybe it's newer, maybe it's young…Oh, b/c it would be falling apart and becoming something new. Or it's just forming, I think it would be falling apart if it was older. Interview 8.

Figure 4.7. Shown are the five samples that the volunteers were asked to describe for question 19. From left to right: gypsum, plagioclase, muscovite, quartz, and halite.

Novice volunteers also associated age with the number of layers a mineral appeared to display. Interview 10 felt that the layers she saw when she studied the muscovite could indicate age. Although, she was unsure if the apparent lack of layers meant that the muscovite was younger, and the layers still need to form, or the muscovite was older and that the sample has, "seen so many days" Interview 10, and so has lost layers.

Relating color to age is another example of an alternative conception that multiple novice volunteers held. As Interview 13 explained he felt that rocks and minerals would either have a darker or lighter color depending on age. Furthermore, when asked why the calcite minerals for question 17 (Figure 4.8) were different colors volunteers such as Interviews 15 and 20 explained that it could be to to age. Interview 15 explained materials change color over time and that she has driven through areas such as Garden of the Gods and saw the rocks on top are different colors then the rocks that are lower in the formation.

> Maybe age could be a factor, I am not sure?...Well, things do change color over time. I don't know the texture on this one is just really different, so I just don't think they are the same, yeah…well, I am from the springs area and drive through the Garden of the Gods, Wilden park pass all the time. And you can see the stuff on top is definitely is different colors then the stuff on the bottom. But I don't feel like the color changes. Interview 15.

Figure 4.8. Shown are the four calcite samples used for question 17.

Interview 18 expressed numerous alternative conceptions related to dating minerals. One alternative conception is that the oldest rocks are on the top and the youngest are on the bottom and she linked fragility to age.

> Yes, so like on a, if you are looking at like a side of a mountain and you can see the different rock layers in it, I thought, younger is on the bottom and oldest was on the top. Because of, not of plate tectonic, but recycling of materials, come up from the bottom. So, the younger ones are on the bottom and the older ones are on the top. I feel like that is right, but I could be wrong… I feel like the softer the mineral, normally the younger it is, because it's more effected by erosion and things. So, I think I would guess this order, from youngest to oldest (her order: mica, dolomite, hematite, chalcopyrite). Interview 18.

She has some education concerning geology, however what she lacks is a strong foundational knowledge of certain geological terms and concepts.

When it comes to color novice volunteers overall believe that the same mineral can come in different colors, however they have different ideas on how minerals can have different colors. One idea, as previously mentioned is that color may have something to do with age. Another common belief is that the color of the mineral can be influenced by the environment in which it formed, as described by Interview 10,

> I think that they, like the color has to do with the exposure to different environmental, different humm, different things in the environment… But if I had to place them. This one probably… I think this one (orange) would have the most exposure to water just based on, because these ones (other 3) have mire of a square shape, so they haven't been moving a lot, or unless this is how pressure formed them to be. But if this one (orange) where in the ocean or a river for example it was moving a lot and had a lot of moving parts and running into things and being picked up and what not. It would change its shape more…Where is like maybe this one (purple) was stuck in just some, like on some hikes, where it's just a bunch of rocks. And it's one of them that's on the very bottom. And so, it just forms, it looks like a square, but it's just… (trails off). I don't know about this one (green). I like this one though, maybe this one was in a swamp, it looks like a Shrek rock. And then, I don't think, maybe this one was extreme cold (Clear). But I'm, I don't know…That was purely based on the color. I mean for all we know this one could be exposed to a bunch of

> sunlight (orange) b/c it has a similar color to what sunlight does (tans our skin) and then this one (green) has more of an oceany kind of lake feel to it, in terms of color, if I was just basing it off of color. But I think there is multiple factors playing on each one. Interview 10.

Interview 14 guessed that the clear, purple and green calcite formed in different types of water. The green calcite possible formed in fresh water, because that color reminds him of fresh water. While it could be the orange calcite's color was influenced as it formed in or around sand. Other volunteers e.g., Interview 11 and Interview 16 expressed the idea that the color of the orange calcite could be the result of the incorporation of sand during formation.

Several novice volunteers typically mixed the terms rock and mineral. While they examined a sample and answered the different interview questions, novices did describe the same sample as both a rock and a mineral, they would transition between the terms as if they were synonymous, e.g., Interviews 9, 14, and 18.

> This has a different texture (fracture side) it feels different than the rest of the rock, or mineral. Question 13, Interview 9.

> I don't know if all rocks are minerals, but that's what goes through my brain, because they all have different chemical compositions, but they are all minerals. Question 14, Interview 18.

> Depending on like if it has a lot of color in it, like a I know if amethyst sits it sunlight it will lose its color, like the richness of its color. And that makes sense, because UV rays are pretty strong. But it's not going to like break down, like weathering, because sunlight by itself isn't that strong. So, may color change? It may crack because like heating up in the sunlight and then cooling down at night. I guess it really just depends really on what kind of rock it is. Yeah, that's all I can think of for sun…Yeah. And then maybe minor erosion if it was a… maybe a metamorphic rock. Question 15, Interview 18.

Several novices would also relate minerals to caves and to mines. Interview 9 discussed her experaince in Carlsbad Caverns and through out the interview mentioned caves and their relationship to mineals and rocks. Moreover, when asked why some minerals are larger than others, Interview 15 explained that it could have something to do with the environment the mineral is in, an area rich in element(s) that are needed, such as a mine.

> I have definitely seen sort of crystalized formations in like mine settings and some of them are pretty large… well, they are usually pretty deep, or deep down so, there is a lot of, I feel there is lot of different elements that could react in different ways. Interview 15.

Another common theme was the interest shown by the volunteers. Novices and experts expressed interest in the samples and potential experiments. For example, volunteers expressed amazement and interest that the quartz sample for question 19 formed into its shape naturally.

> Can I ask, did it have this shape, or was it given this shape, was it made like this in nature?... Oh, that's awesome. Interview 10

Furthermore, after she examined the feldspar sample in question 13, Interview 9 expressed how cool the sample and texture of the mineral was and how she had forgotten how much she enjoyed looking at rocks. Interview 6 talked about how much he enjoyed taking a geology course in high school. Volunteers even stated how peaking interest in minerals and geology was kindled.

> I will say that this is peaking my curiosity as to geology as a whole. Interview 2.

Self-Efficacy

Question 4 asked novice and expert volunteers to "please circle how confident you are that you will do well in a science course." The question was on a scale of one, being the lowest, to five as the highest (Appendix A). The lowest confidence score recorded was a three and was given by only three novice volunteers. The average answer for all 22 interviews was a four.

Although, most novices answered question 4 similarly to the experts and circled higher confidence numbers of four or five, novices showed less confidence in their answers. Tables 4.2 and 4.3 show that novices are more inclined to use validation phrases such as: “I don’t know” and “I am not sure”. The second column shows how many times this phrase appeared in all 15 novice interviews and seven expert interviews. For novices the phrase “I don’t know” appeared 372 times compared to 31 times for experts. The third column is how often a phrase was said by a volunteer. On average a novice said the phrase “I don’t know” 25 times in comparison to the expert volunteer of four times per interview.

Table 4.2 Confidence Phrases Used by Novice Volunteers.

Common Phrase	Novice: Sum	Novice: Average	Novice: Range
I don’t know	372	25	1-56
I am not sure	71	5	0-17
I’m no expert	4	0	0-2
I have never thought about this	4	0	0-1

Table 4.3 Confidence Phrases Used by Expert Volunteers.

Common Phrase	Expert: Sum	Expert: Average	Expert: Range
I don't know	31	4	2-11
I am not sure	17	2	0-7
I'm no expert	0	0	0
I have never thought about this	3	0	0-3

Novices often apologized for their answers or lack of answers. It was common that novices expressed that they had little knowledge about minerals and what properties make a substance a mineral.

> I can't even quite remember what distinguishes a mineral, it's been that long…I'm a not 100% sure what defines a mineral from the rest of it. Interview 9.

Some questions would go unanswered as the volunteer lacked confidence in his/her knowledge and understanding about minerals.

> Like I really don't know, and I don't want to call it something that, like I know about elements, I don't know about minerals and I don't want to say anything, because I know each science is very specific about their terminology. So, I don't want to offend an entire section of science. Interview 4.

Novice vs. Expert

I used IBM-SPSS to test if there is a significant difference between novices and experts in the number of alternative conceptions reported by each group. The seven experts were paired with seven novices of the same gender identity and that grew up in the same or similar environment, e.g., two females, grew up in a suburb. The volunteers were compared using these variables because past research suggests these factors may influence their answers to interview questions (e.g. Kusnick, 2002; and Monteiro et al., 2012). Due to the small sample size I could not match all experts with novices with the same background. I therefore matched the experts with novices of similar environments, e.g., an expert from a small town was matched with a novice from a suburb not a city.

My results show the assumption of equality of variance was violated (Levene's Test for Equality of Variances, $F = 5.24$, $p = .041$). Therefore, the equal variances not assumed results were interpreted. The results of an independent sample t-test suggest that there is a significant difference between the number of alternative conceptions reported by experts and novices, $t\ (7.82) = 6.4$, $p < .001$. Experts ($M = 8.29$, $SD = 5.5$) reported significantly fewer alternative conceptions than novices ($M = 44.57$, $SD = 13.96$).

The common terminology used to describe the samples and discuss mineral processes differs between novice and expert, Tables 4.4 and 4.5. The third column shows that novices on average used the term layers seven times per interview, while the average for the experts is one per interview. Out of the four terms that are listed in the table, the term that was mentioned the most for both expert and novice was color. In total novices mentioned color 177 time and experts a total of 61 times.

Table 4.4 Terms Used by Novices.

Common Terms	Novice: Sum	Novice: Average	Novice: Range
Layers	109	7	1-20
Color	177	12	4-18
Clear	43	3	0-15
Shine	52	3	0-17

Table 4.5 Terms Used by Experts.

Common Terms	Expert: Sum	Expert: Average	Expert: Range
Layers	4	1	0-4
Color	61	9	2-19
Clear	3	0	0-3
Shine	7	1	0-3

Although, both novice and experts discussed color, novices tended to focus on color more often than experts. When asked to draw the potassium feldspar sample from question 13 most novices first looked for the right color pencil to get the correct color (Appendix C). If they did not begin with color, they often began by drawing the perthitic texter, typically described as layering, and explained they noticed the change between lighter and darker colors. The experts would also begin by drawing or describing the perthitic texture, but their focus would often shift to the identification of the mineral, the mineral's chemical composition, and its hardness. Three out of seven experts did not color their drawings but noted the color later in their descriptions, e.g., the color is pink or salmon (Appendix C).

> I can't find the color I want… Yeah I see the lines right there (perthite). It appears on both sides. I feel like it is layered as well…I see all these little lines in there, yeah… Generally smooth… It's shiny. Interview 15.
>
> I am pointing out exsolution lamellae… Which means that this was a feldspar that formed at high temperture and as it cooled, b/c it is a potassium bearing feldspar it can actually have a little bit of sodium in it. And when it cools the sodium feldspar has a different crystal structure, so it exsolves from the potassium feldspar… creating the lines that I drew. You can sort of make them out on this face, but not as well as on that face. They sort of come through, kind of like that (drawing). I need a pink (looking at color pencils) or something like a salmon color… This mineral formed when a silicic magma or felsic magma cooled at some depth within the earth's crust, slowly to allow a large crystal to form. It was

> probably a part of a granitic rock at one point in time. It's a beautiful potassium feldspar crystal. Interview 22.

For question 16 the volunteers were asked if they believed scientists could date minerals. Both novices and experts responded yes, however novices tended to mention relative dating while experts would discuss radiometric dating. Novices commonly understood that older material is found lower in a formation and younger rocks and minerals are located at the top. If novices discussed radiometric dating, they would mention carbon dating as a possible method to date minerals and rocks.

> Yes, they can. They can use carbon dating. They can also look at the rock formation that they are studying and they can look at the layers and they can guess-ti-mate, which is older or younger by how high or how low they are on the rock formation. Interview 11.

> Okay so, I do think they can tell how old they are by the sediment layers, I guess. I am not thinking that you can carbon date rocks, I don't think you can, you might be able to, but I think sediment has a lot of the data you use for that. Interview 6.

In contrast, experts commonly began by explaining radiometric dating and the different examples of radiometric dating and how the process works. Some experts mention relative dating, but the focus of their answer was on absolute dating.

> Well, I am trying to think if this is universal, it is almost close to universal, the only way you can date minerals is through some analysis of radioactive parent and stable daughter pairs. And that requires breaking down the mineral into its atoms essentially and then measuring them mass of those atoms to know which element and isotope they are. And then taking those ratios and putting them through a mathematical equation, which can give you the age. It's also, a complex question of how old is a mineral, in that you can apply many different techniques in order to determine the age of mineral, what you have to be careful of is whatever that age is that you get from the mineral it may not be the actual age of the mineral, but of some other event that those isotopic ratios record. So, it be cooling of the mineral too. So, I am going to assume how old the mineral is, is when did the mineral form right. Interview 20.

All volunteers used knowledge they have gained from previous science courses, e.g., geology, chemistry, biology, and physics to answer questions regarding how minerals form and what make up minerals.

> Something I understand to be true about minerals, oh man that's a book… I can write the definition of a mineral. And I understand each component of the definition intimately…I have also contributed to textbooks on minerals so. Question 11, Interview 20.

> So, magma is a liquid and it crystalizes or hardens, become solid, forming this mineral, with only the elements that are in this mineral, that were present, so. Just one solid mineral. Question 13, Interview 17.

Volunteers also use knowledge they gained outside of the classroom from family trips and by everyday observations they have made about the world around them, e.g., their skin tans in the sun or their toys and clothes bleach in sunlight. Whether gained in or outside the classroom both novice and experts used their prior knowledge about minerals and geologic processes to answer the interview questions.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A mineral identification lab is generally among the first labs taught to entry level college students and it is often their initial introduction to minerals. It is important that this introductory lab provides students with a strong foundation of geological concepts, as many geologic topics rely on a firm understanding of these concepts learned in the introductory lab.

There is some previous research that examines the alternative conceptions of the novice earth science student, however this research is limited and does not completely uncover the initial knowledge state of the earth science novice (Anderson & Libarkin, 2016; Libarkin & Anderson, 2005; and Monteiro et al., 2012). My research adds to this research and provides teachers with information about the efficacy of the novice geologists and an awareness of a student's background knowledge.

Instructors should be made aware of their student's alternative conceptions, because an inaccurate foundational knowledge of these conceptions can impede a student's ability to learn new geological concepts and can affect a student's self-efficacy as they begin to learn about minerals and other geological concepts.

My research shows that novices begin a intoductory geological course with little knowledge about minerals. Moreover, what prior knowledge novices do have is typically polluted with alternative conceptions that can impede their ability to learn about minerals and other geological concepts. My research shows that common alternative conceptions are that minerals should have a certain density and minerals look and feel a certain way. It was also expressed by novices that if a mineral is clear or has planer faces that it is a pure crystal or mineral. These alternative conceptions may make the mineral identifaction lab more difficult for novices if they are to identify muscovite, amphible, or hematite when they believe minerals look like a quartz sample with planer faces seen in a museum.

Instructors should be cautious with terms they use, because these terms can already mean something different to novices. The results show that novices are aware of the term and concept of layers and layering and will relate this process to different concepts like how minerals form and their age. Therefore, instructors need to be clear on what terms like layering mean to geologists.

Novices also do not understand the difference between a rock and a mineral. They commonly interchanged the terms when they answered interview questions and described samples. Many novices admited that they do not know what makes a substance a mineral and when asked to list mineral names they listed rock names, such as granite and sandstone. However, it is clear that experts have learned about minerals, because when they were asked what they knew to be true about minerals all seven experts listed the different characteristics, e.g., crystalline structure, solid, and inorgainc. Since, all seven experts answered this question the same it is clear they believe these properites are important to know in relation to minerals. Experts know what these terms mean and why minerals fit these descriptors and rocks do not. Therefore, as experts, instructors need to be clear in their explanations of these properties.

Instructors should be aware that novices do have more alternative conceptions about minerals and mineral processes than experts. The results of an independent sample t-test suggest that there is a significant difference between the number of alternative conceptions reported by experts and novices.

Additionally, novices tend to think more concretely about minerals and tend to focus on characteristics like the color of a mineral more often than experts. Novices are inclined to find significance in a mineral's color, e.g., it can denote age or shows what environment the mineral formed. However, experts can think more abstractly about minerals and often focus on other characteristics such as hardness, does the sample react to hydrochloric acid, and the mineral's chemical composition. Moreover, due to the number of validation phrases, e.g., "I don't know" used by novices indicates that novices have less confidence in their ability to list, identify, and answer questions about minerals and mineral processes.

It also important for instructors to note that novices do have an interest in learning about minerals. The muscovite, quartz, and chalopyrite samples all inspired interest due to their shape, color, and/or flakiness. Novices made comments that they enjoyed the geology or earth science class that they took in middle or high school, they enjoy looking at rock and mineral samples, and because of the interview their interest about minerals has been peaked. Although, novices have alternative conceptions when entering a mineral lab overall, they do want to learn about minerals and mineral identification.

Both instructors and students can benefit from this reseach as professors can use this research to formulate their classroom activities and potentially help their students move away from their alternative conceptions. Their students will gain correct scientific concepts, and create a strong foundation upon which their students can build. With a correct base knowledge of the subject matter students will then be able to learn more complex concepts.

REFERENCES

Anderson, S. W., & Libarkin, J. C. (2016). Conceptual mobility and entrenchment in introductory geoscience courses: New questions regarding physics' and chemistry's role in learning earth science concepts. *Journal of Geoscience Education*, *64*, 74–86.

Ausubel, D. P., (1964). The transition from concrete to abstract cognitive functioning theoretical issues and implications for education: *Journal of Research in Science Teaching, 2*, 261-266.

Bruning, R. H. (1995). Schraw GJ, Ronning RR. *Cognitive psychology and instruction* (2nd ed.). Upper Saddle River, NJ: Merril/Prentice Hall.

Cheek, K. A. (2010). Commentary: A summary and analysis of twenty-seven years of geoscience conceptions research. *Journal of Geoscience Education*, *58*, 122–134.

Dahl, J., Anderson, S., & Libarkin, J. (2005) Digging into Earth Science: Alternative conceptions held by K-12 teachers: *Journal of Science Education*, *6*, 65-68.

Darling-Hammond, L. (2000) How teacher education mattes: *Journal of Teacher Education, 51*, 166–173.

De Jong, T. (2010) Cognitive load theory, educational research, and instructional design: Some food for thought: *Instructional Science, 38*, 105–134.

Ding, M., & Li, X. (2014) Transition from concrete to abstract representations: The distributive property in a Chinese textbook series: *Educational Studies in Mathmatics, 87*, 103-121.

Forcino, F. L. (2013) The importance of a laboratory section on student learning outcomes in a university introductory earth science course: *Journal of Geoscience Education, 61,* 213–221.

Francek, M. (2013) A compilation and review of over 500 geoscience misconceptions: *International Journal of Science Education, 35*, 31–64.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008) Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers topic- specific knowledge of students: *Journal for Research in Mathematics Education, 39,* 372–400.

Hulleman, C. S., & Harackiewicz, J. M. (2009) Promoting interest and performance in high school science classes: *Science, 326*, 1410–1412.

King, C. J. H. (2010) An analysis of misconceptions in science textbooks: Earth science in england and wales: *International Journal of Science Education, 32,* 565–601.

Krathwohl, D. R. (2002) A revision of Bloom's Taxonomy: An Overview: *College of Education, The Ohio State University, 41,* 212- 218.

Kusnick, J. (2002) Growing pebbles and conceptual prisms - Understanding the source of student misconceptions about rock formation: *Journal of Geoscience Education, 50,* 31–39.

Leinhardt, G., Crowely, K., & Knatson, K. (2003). *Learning conversations in museums.* Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Libarkin, J. C., & Anderson, S. W. (2005) Assessment of learning in entry-level Geoscience courses: Results from the Geoscience Concept Inventory: *Journal of Geoscience Education, 53,* 394–401.

Libarkin, J. C., Kurdziel, J. P., & Anderson, S. W. (2007) College student conceptions of geological time and the disconnect between ordering and scale: *Journal of Geoscience Education, 55,* 413–422.

Monteiro, A., Nóbrega, C., Abrantes, I., & Gomes, C., 2012, Diagnosing Portuguese students' misconceptions about the mineral concept: *International Journal of Science Education, 34,* 2705–2726.

Paas, F., Van G. T., & Sweller, J. (2010) Cognitive load theory: New conceptualizations, specifications, and integrated research perspectives: *Educational Psychology Review, 22,* 115–121.

Prawat, R. S. (1992) Teachers' beliefs about teaching and learning: A constructivist perspective: *American Journal of Education, 100,* 354–395.

Sadler, P. M. (1998) Psychometric models of student conceptions in science: Reconciling qualitative studies and distractor-driven assessment instruments: *Journal of Research in Science Teaching, 35,* 265–296.

Schoon, K. J. (1992) Students' alternative conceptions of earth and space: *Journal of Geological Education, 40,* 209–214.

Schwartz, D. L., & Goldstone, R. (2016) Learning as coordination: Cognitive psychology and education. In L. Corno & E. M. Anderman (Eds.), *Handbook of educational psychology* (61-75). New York, NY: Routledge.

Sewell, A. (2002) Constructivism and student misconceptions: Why every teacher needs to know about them: *Australian Science Teacher's Journal, 48,* 24–28.

Sexton, J. M. (2012) College students' conceptions of the role of rivers in canyon formation: *Journal of Geoscience Education, 60,* 168–178.

Zimmerman, B.J. (2000) Self-Efficacy: An essential motive to learn: *Contemporary educational Psychology*, *25*, 82–91.

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

IRB Approval Letter

Institutional Review Board

DATE: April 10, 2018

TO: Amanda Manzanares

FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [1176179-3] Misconceptions, Alternate Conceptions, Scientific Knowledge and Self- Efficacy of the Novice Geologist Regarding Mineral Identification

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED

APPROVAL DATE: April 8, 2018

EXPIRATION DATE: February 18, 2019

REVIEW TYPE: Expedited Review

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB has APPROVED your submission. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on applicable federal regulations.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of February 18, 2019.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

Amanda Thanks for submitting clear and through amendments/modifications. Best wishes with your research and don't hestiate to contact me with any IRB-related questions or concerns. Sincerely, Dr. Megan Stellino, UNC IRB Co-Chair

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records

Consent Letter

CONSENT FORM FOR HUMANPARTICIPANTS IN RESEARCH

UNIVERSITY OF NORTHERN COLORADO

Project Title: Alternate Conceptions, Scientific Knowledge and Self- Efficacy of the Novice Geologist Regarding Mineral Identification

Researchers: Amanda Manzanares, Dr. Steve Anderson

Email: amanda.manzanares@unco.edu, steven.anderson@unco.edu

Phone Number: (303) 489-3558, (970) 351-2973

For my thesis I hope to aid both teacher and student by providing teachers with additional background information on their students. I hope that my findings will help instructors when teaching mineral identification labs. If you agree to participate in this research, you will be asked to complete a confidential approximately 40-minute interview. You will be asked to answer questions pertaining to your knowledge about minerals such as, what is a mineral made of? You will also be asked to give some background information that will not reveal your identity, such as what year were you born, what science classes have you taken? You will be asked to draw samples and you will have the opportunity to examine samples closely if desired. The interviews will be videotaped in a manner that will protect your identity. The camera will be at an angled that will not show or record the volunteer's face.

Your choice to participate in this research will not impact your experience at the University of Northern Colorado nor your grade if you ever choose to take a Geology 100 course at the University of Northern Colorado. There are no expected benefits or risks to partaking in this research. If you would like to participate in this research, please sign and date this document below. You are free to stop participating in the interview process at any point. If at any time during the interview you have questions and concerns about this research, please let me know so I can address them.

At the end of the study we would be happy to share your data with you at your request. I will never ask you to provide your name, bear number or any information that can associate your interview with your identity. I do not have access to your personal information.

At the completion of the interview you will be compensated with free fossil, rock and/ or mineral samples of your choosing. You will not be offered other incentives, such as extra credit, to be involved in the study.

page 1 of 2 ___________

(participants' initials here)

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact Sherry May, Office of Research, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970- 351-1910.

____

Your full name (please print)

Your signature	Date
Researcher signature	Date

Interview Questions

1) What year were you born?

2) What is your gender identity?

3) Did you grow up in a city, suburb, small town, farm, or a combination of one or more areas (please elaborate)?

4) Please circle how confident you are that you will do well in a science course?

1 2 3 4 5

Low High

5) How many earth science classes have you taken? Please mark a X in the appropriate box below.

	High School	College	Other (please explain)
Geology			
Oceanography			
Meteorology			
Other (please explain)			

6) What science classes have you taken? Please mark a X in the appropriate box below.

	High School	College	Other (please explain)
Physics			
Chemistry			
Biology			
Other (please explain)			

7) What is the highest level of math that you have completed?

	High School	College	Other (please explain)
Algebra			
Trigonometry			
Pre-Calculus			
Calculus I			
Calculus II			
Other (please explain)			

8) What is your major(s)? What is you minor(s)? Are you undeclared?

9) Are you considering a major in Science, Technology, Engineering, Math (STEM)? If your answer is yes, what field are you considering?

10) Please list any minerals that you can name.

11) What is something that you understand to be true about minerals?

12) Can you think of any minerals that you encounter every day? (ex: minerals that you eat or drink, or that you use to compete tasks at school, work, and/or at home).

13) Please write down your observations and draw the mineral. How did this mineral form?

14) Is this a mineral why or why not?

15) What would happen if I placed a mineral in sunlight for a year? Why?

16) Can scientists tell how old minerals are? If it is possible please, order these minerals from youngest to oldest. Give a short explanation of why you understand one mineral is older or younger than another mineral. Why might scientist want to date minerals?

17) Are these the same mineral? Explain your answer.

18) What would happen if these minerals were placed in a fire for a year? Why?

19) List as many differences between these minerals that you can.

20) What would happen if a mineral was buried for a year in Environment A vs. Environment B? Why?

21) What would happen if a train stayed on top of a mineral for a year? Why?

22) Why are some minerals larger than other minerals? Can the same type of mineral form both large and small minerals? Why?

23) What are minerals made of?

24) How many minerals do you feel that you could learn to identify in 2 hours? Why?

APPENDIX B

INTERVIEW TRANSCRIPTIONS

All transcriptions are formatted the same, beginning with my name, the years I have worked on my thesis, who is being interviewed e.g., UG= undergraduate student, G= graduate student, P= professor, and the duration of the interview. All transcriptions also have a description of the shorthand used, an explanation of how the interviews have been coded, and in bold are the synopses of the volunteers' answers to questions 10 thru 24.

The first transcription shown is Interview 2. The complete transcription including the introductory information is given. The shorthand description and coding information are not repeated below for the following interviews, Interview 19 and Interview 24.

Interview 2

Mandy Manzanares

Thesis 2017-2019

UG: Interview 2

1 video, 56 minutes 47 seconds

Me= M

Volunteer= V

Shorthand: UG= undergraduate student, G= graduate student, P= professor, qtz= quartz, feld= feldspar, b/c= because, HS= High school, both mica samples are muscovite and both I label in interview as mica.

If in italics not sure what said.

I also have things in () which give more info, or specify if I can't make out something

Bolded: synopsis of answers

In purple: Confidence. Words and sentences are highlighted in purple when they relate to the volunteer's confidence, lack of confidence and self-doubt. Examples: I know, I don't know, I'm not sure, I'm no expert, the use of I guess, probably or maybe, I never thought about this, nervous laughter and when they try to justify their answers or feel they maybe answering the question incorrectly.

In orange: Prior knowledge. Words and sentences are highlighted in orange when they relate to the volunteer's prior knowledge about minerals and science processes. Examples: If they use terms related to science; e.g., elements, translucency, luster and layers. If they reflect on a past experience in or outside of the classroom to answer a question. If they use analogies. If how they answer a question is influenced by a prior answer. If their answer speaks to their prior understanding of minerals. If their knowledge about the sample influences their answer, e.g., they know or believe they know the sample is metallic and metals react a certain way in a fire. Also, if they speak about how they know they learn, e.g. visual learner or auditory learner.

In green: Interest. Words and sentences are highlighted in green when they relate to the volunteer's interest about minerals and science processes. Example: If the volunteer uses terms like cool or interesting when talking about the samples. If the volunteer shows interest in knowing more about the sample, subject, and or question (e.g., cool sample, I forgot how interesting rocks are, this would be a fun experiment).

In blue: Personal notes or something to take note of. Words and sentences are highlighted in blue if I made an observation during the interview that I added as a note. Also, highlighted in blue are volunteer's answers I want to easily locate, e.g. # 16 if the volunteer list the minerals from youngest to oldest.

Common terms/ideas: layers 10) Confidence, past knowledge blank, says all can think of is elemental stuff. 11) past knowledge, what makes up the environment, different chemicals make ups of different environments. 12) Confidence, past knowledge, pumice, tap water and what's in it, pencil lead (graphite). 13) Confidence, interest, past knowledge, bit unsure about getting started drawing, formed layer by layer under pressure, maybe a granite, not a mineral b/c different stuff in there, dense, sedimentary b/c layers, broken from a larger piece, pinkish, hardness 5.5-6, jagged edges not magnetic. 14) Confidence, interest, past knowledge, uniform, made of one material and so is a mineral, curious idea about environment and minerals, soft maybe chalk or talc. 15) Confidence, past knowledge, take longer than a year, would have an effect, b/c sun effect many things, but minerals take a while to change so need like a million years. 16) Confidence, past knowledge, interest, notes, yes, can watch things form and use technology, Oldest to youngest (starts with dolomite, muscovite, chalcopyrite, hematite) the crystalline structures would take the longest to form, quartz (dolomite) Mica then, b/c it is metallic longer to form than the thing that I know nothing about (points to hematite), date to predict natural disasters, learn about the earth, b/c make up the earth and out of curiosity. 17) Confidence, past knowledge yes, the same, distinct similarities, same smoothness (feel), how it was broken (cleavage), similar weight, don't think need to test hardness, something makes the color different but still the same, maybe orange calcite not the same, but other 3 are. 18) Confidence, past knowledge, notes, want to know heat of fire, if there is a change it would be talc b/c less dense, softer, smoother, see layers in the talc and metals (referring to galena has lead) are more

heat tolerant, so a physical change to talc maybe melting or vaporization, maybe discoloration to galena. 19) Confidence, interest, past knowledge, notes, recognizes mica b/c of previous sample, focuses on layering and shine, feels they are all related, maybe in similar in location, talks about qtz being a purer version, halite maybe had a point like qtz, pair qtz and halite and gypsum and muscovite, muscovite could become gypsum, flakier, (mica) heavy (plag) than the rest. Crystal (qtz), plag really throughs him off in comparing them. 20) Confidence, past knowledge, A more than B basically describes chemical weathering vs. physical weathering. 21) Past knowledge, depends on the mineral, kaolinite turn to powder, something full of lead like galena not change or would need more time and weight on it. 22) Confidence, past knowledge, relate to past science classes about mass, density and volume, think of things like something with lead (galena) is just as heavy as a larger mineral but in a smaller space, relates this to why bigger and smaller, less pressure and temperture then less constrained and more space to grow and where water carries minerals in to create he says, limestone, these can grow exponentially with enough space. 23) Confidence, interest, past knowledge feels that some of the "materials" he saw in the interview were more complex, so seems minerals have to be made of something more complex then chemicals and elements otherwise is unfair, unless there are 100's or 1000's of chemicals and elements he is unaware of. 24) Confidence, refers back to Q10 doesn't want to offend anyone say the wrong name, 25-50, some easier to identify then others.

Intro: I start by explaining the layout of the interview, with background and then mineral questions.

1) 1998

2) Male

3) both

4) 4

5) HS: meteorology and earth science

6) HS: Chemistry, Biology

7) HS: Algebra 2

8) undeclared (ASL interpreter)

9) Not now

M: So today, umm here's the interview, umm if you like, after initially if you prefer just that we talk umm for answering the questions that is fine. I'll probably ask to read some of your answers. Umm the first part is just more of a background information and then you'll be asked different questions concerning minerals and some will include samples some won't. They'll be also you can umm draw for some if you want to draw for all, you can. And you will be provided with color pencils and extra paper if you want it.

V: Okay

(Q 10)

Laughter from both when seeing the first question on minerals

M: That's alright, take your time.

V: I have never thought about this. Laughs.

M: write down anything that comes to mind.

V: Okay

More laughter

M: That you feel is a mineral name, ok something that you know

V: Alright, umm. Laughter. For some reason all I can think of is like elemental stuff, but that is not exactly the same. We'll move on from that for now.

M: We can come back to it and we can come back to different samples once, or anything or different questions at different points.

(Q 11)

M: Do you can to elaborate on your answer? So, you say they make up the environment in many ways, do you have a specific idea? And if you like to answer verbally or by writing that is okay.

V: umm, essentially just like the different layers of the earth and like various make ups of, like how they are made and where they are at and things like that. Would be my answer for that, would be my answer for that.

M: Okay

V: So, like volcanic rock vs like deep sea stuff, the different chemical makeups of them and then and what you might find in a mountainous environment vs. desert and things like that.

M: Very good.

(Q 12)

V: I think, umm no, (laughter).

M: Feel free, we can always come back to that.

V: Okay… I think that, is that how you spell pumice, pumice stone

M: Yeah...

V: Exfoliations?

M: Umm humm. That will be close enough.

V: laughs

M: I'm not a great speller, so…

V: Okay, I'm not entirely sure what is in tap water.

M: In what is it?

V: In Tap water.

M: Ah, in tap water. Umm humm.

V: Tap water. I think, I'm not sure if that qualifies either. I haven't done many categorizing of minerals and the difference between rocks and minerals and so on and so forth.

M: That's okay. That's totally fine.

V: Okay

M: So, would you like to go back to 10 or would you like to move on to 13?

V: I think we can move onto 13

M: okay

(Q13)

M: So right now, as I said I really would like you to draw it, but if you for any of the other samples feel free to draw those as well.

V: Okay

M: So, you have some color pencils, and this is our sample. And if you what to you know, whatever you like to. Whether you are familiar with this or not, even if you are not, if you want to try hand at this is a standard mineral ID kit for an intro student. And so, this is called a hand lens and is used to actually, basically it is like a magnifier, umm there are different ways to test minerals. So, we have a magnetite and you have different things. This is called a hardness, and this is a streak plate, you can test what color happens again this is glass for hardness if you want to test anything, do not hold it like this b/c it can break in your hand. So, make sure that it lays flat and you also have a course mineral that, can help with hardness. Even if you just want to play around with them that is fine.

V: Okay, fair enough, so am I drawing this?

M: Yes please, and any observations that you can see, or you want to write anything down or speak them out load either way.

V: And I will want to put them here? (Gesturing if should draw/write on the interview paper or extra paper)

M: Either way, I will keep everything together, I gave you this, so you would have plenty of room to draw, if you would like to draw it on here you can.

V: I am going to write my observations first. Just based off of weight it seems kind of dense. Um, it has got some luster to it. Some shine. I don't know if there is a scale for that, but I'm sure there is somewhere. Umm.

M: That's just an ID number.

V: Umm…

M: (Referring to his writing) So what do you mean by layers?

V: That you can see the uniform building of something, they are not all 100 % uniform, but I would say that they are pretty close as far as the structure is concerned. It does not scratch off, I guess that is a part of the hardness scale, not entirely sure what else I should write about it.

M: Whatever comes to mind.

V: Jagged around the edges, probably broken from something larger, yeah. I guess I will draw it over here. Does it matter what angle, or should I do multiple or?

M: It is completely up to you.

V: Okay

M: There is not right or wrong answer here, it's just answers

V: Awesome, I can do that. I am going to draw two faces. I promise that I will not put in every single line here (referring to texture).

M: If you want to than… So, you mentioned that you think it has something to do with growth. Isn't that what you said?

V: Yeah, like it seems to be from a piece of something larger, and the layers you can tell that's probably that it was made, I guess that is what you could say, I am no expert obviously. But if I were to guess the type, I would assume sedimentary b/c it is layer upon layer upon layer. But, bases upon the general hardness of it, I would not be so sure. And like I said I could not tell you if it was a rock or a mineral, to be honest.

M: That is so okay.

V: Not sure, what I would draw on this side, but as far as the shine of it, that is a bit difficult to try and get in a drawing.

M: Yeah. You look good, so.

V: So, what is your like overall end goal to this research? Like?

M: My end goal is to be able to help teachers, umm help their students, so they can begin learning more about minerals faster. And if there is maybe any confusion or concepts that need to be adjusted. Umm, then I want, I would hope that my research would be able to prepare teachers in order to make the introduction to Geology 100 labs more…

V: Compressive to new students.

M: Yes.

V: Interesting, cool. Well, I am glad that I can help with that.

M: Me too.

V: And how did you get started on that as your thesis?

M: Umm, some of it came from my advisor and him beginning with things that he is interested in and learning and how students learn and when are they beginning to learn certain concepts and things are becoming ingrained. And then I think as ai began to teach, I realized how important beginning labs are, and for student comprehension and so it kind of just grew from there, on where things begin and how then and what sort of things do we need to start addressing early on to get those concepts starting to be ingrained and worked through. It was quite an up and down process, I thought I knew what I was going to do and then that was like nope, and then I changed it and I think it is like heading in ways back, but different then I initially thought my research was going.

V: Interesting.

M: But it began with a lot of reading, so…

V: I am sure, I am still fresh on the whole college thing, to go as far as you have, so on and so forth. (Test orthoclase on the steak plate). Okay, I'm not entirely sure what that means, but… (tests on glass) so it is not Dimond hard.

M: what I can say is that you can press harder if you like, you do not have to be soft, you can bear down if you like to.

V: Okay, I understand that would be likely how you would test that, so it left a mark, I don't know how far, I'm like, the scale, like I said.

M: So, you can see there is a glass plate on there (pointing out hardness scale).

V: Right…

M: So…

V: So now I want to see if the nail, if it between a nail and a glass plate, right? I mean… and that did not leave a mark, so that would be like a 5.6 hardness or something like that. So, then this would be the talc plate?

M: Ah, yeah that is a ceramic plate.

V: Ceramic, okay?

M: It is usually done, for certain minerals when they are, if you really press down and rub it across, it will give off a certain color, umm, some do some don't.

V: Okay, and then aside from trying to draw it, what would be the point of this? (asking about hand lens)

M: Especially for when, you have, uh, certain minerals or rocks if you what to see something up close. So actually, bring the lens to your eye first, and then bring the sample up until it is in focus.

V: Okay. Well, that was way more detailed then what I was doing so, that is pretty cool.

M: So that is what that is, it is called a hand lens so.

V: And so, if you double up, what does that do?

M: It should make it stronger.

V: Yeah, it does. Okay. Cool. So, if you were to go into a Geology 100 class is this something that you would buy yourself?

M: Yes, and I think that it is about 5 or 10 dollars at the bookstore.

V: Okay, cool.

M: Do you feel that you would like to move on?

V: I believe so. I should probably answer how this mineral formed.

M: Ah, yes.

V: Uh, humm, is this granite? Any kind of granite? Probably not maybe, I don't know.

M: It's found in granite.

V: Okay, interesting, I suppose that make sense though, granite is like a mix of all of them, so, umm.

M: What made you think of granite?

V: The color specifically, b/c it has lighter whites, pinks, lighter white again, it is just a real mix.

M: Are you…

V: And the luster of it, so it made me think of granite as well. And that is all I can say about that. Just layer by layer b/c of pressure.

M: Sounds good to me.

V: Alright. Is this a mineral? This where I am stumped. (still looking at the orthoclase)

M: As I said there is no right or wrong answer. You are not supposed to be an expert.

V: Alright, far enough. Umm, I am trying to think back to all of the science classes that I have taken and trying to remember classification stuff, it has been a very long time. And so, I am going to say that it is not.

M: Why?

V: To the fact that there is like seemly different types of stuff in here.

M: Okay

V: And that might be the reverse of what is true

M: So, you are referring to all of the different lines in there? So, you think those are different?

V: So, there is at least two different types of things in here, at least that is what I think.

M: Yeah.

V: So…

(Q 14)

M: So, this is actually for the next one as well so…

V: Okay.

M: So, but you can, if you like, and I also that, but you can put that over there so, here we go (really just jumble of words, volunteer sets orthoclase off to the side). Okay. So, this is the sample specifically for number 14.

V: Oh, it is very soft.

M: Very soft.

V: Extremely soft, I wouldn't be surprised if this was talc. Or chalk.

M: it is very soft, yes.

V: so, I am just supposed to say that this is a mineral or

M: yes, and why you think it is or is not.

V: okay, so going based off of what I just made up for that one, this one appears to be a mineral to me.

M: Why do you think that?

V: Umm, it is all very uniform and it doesn't seem to be too heavy or created by something that would be intense.

M: Meaning?

V: Like environmental forces basically. I mean it could be volcanic, but I am still not an expert, it just seems like something that you would find anywhere and everywhere.

M: So, if it was made by a volcano, would it be a mineral, or would it not?

V: Yes, only b/c that would be a substance in it of itself one thing, maybe, as I just said the definition of what I just came up with. That (referring to orthoclase) being multiple materials this seeming to be only one, would make it a mineral in my mind.

M: Okay, very good.

V: So, I will write that down here.

M: Sounds good.

V: I will say that this is peaking my curiosity as to geology as a whole.

M: Well, that's always good. I like to hear that. Well I think I will set these two over here, if you are ready to move.

V: Absolutely.

(Q 15)

M: Okay so, we'll go to number 15. Umm, so we do not have a sample for this one, this is just kind of more thinking, yes conceptual (responding to volunteer), umm, so again if you would like to write it down or speak or both umm for number 15: What do you think would happen if a mineral was place in direct sunlight for a year?

V: Is this just like… I am trying to think of the setting for this.

M: Either outside or in a window sill, just more than anything, the question is asking would the sunlight have any effect on the mineral itself.

V: Umm, I am wishing that I had taken some sort of course, anyway. Umm, I don't think that it would have a substantial effect based on the fact of just like… sunlight has effects on lots of things for lots of reasons. And I think it takes more than a year for sunlight to affect a mineral.

M: Do you feel

V: I think that eventually it would, if that answers that question?

M: Okay, do you have an idea

V: Not after a year, potentially

M: How long do you think it might take?

V: Umm, just based on the age of like minerals in general, probably well over a million.

M: Okay

V: But that is just like I said, spit balling it really. But yeah, I think that in a year there wouldn't be any effect on a mineral in sunlight.

M: Okay

V: B/c it takes time for minerals to change, based on what I think I know.

M: Alight

V: yeah, so do you want me to write that down?

M: Sounds good.

(Q 16)

M: There's a lot of, kind of, this next question there is kind of a lot of parts to it. But I'll put four different samples in front of you. So, the first part is, do you think scientist can tell how old minerals are?

V: I believe so

M: Why do you think that?

V: Just the way different minerals and substances are formed. Like you can, like there is a way for scientist to see that happen in a very quick manner. So, for instance, in a volcanic situation you can physically see the process from magma/lava to the rock formations that they make. Verses something that's crystalline since the beginning, essentially and then just the way that technology has developed over time we can get a very close look at how things are structured and what they are built up and made of and things like that.

M: so, you think the structure might tell them how old it is?

V: yeah, I think that is part of it along with like the substance itself if you can know the half-life by carbon dating or whatever. Like the atomic structures tell a lot about different substances so in short yes, I believe they can tell.

M: Very good. Umm, if you think it is possible do you think you could just by kind of observing this and looking at them or feeling them or anything tell maybe what or if we could date these do you think that you feel that you could put them in some sort of order?

V: Um, I think I could speculate, I could definitely try.

M: Go ahead.

V: Are you allowed to tell me what this is? (holding muscovite) I am very bad at, this is just interesting, I don't know if I have ever seen this before.

M: This is, I'm not quite sure (referring to can I say what it is or not) It is called mica.

V: oh, interesting, I have heard the name, but I have never seen it, so.

M: I'm happy to peak your interest about all of this so

V: I think that's right

M: so, which one do you think is older?

V: Oldest to youngest (starts with dolomite, muscovite, chalcopyrite, hematite)

M: Any reason, what was your reasoning behind this?

V: so, based on what I said for 15 and the first part of 16, the crystalline structures would take the longest to form. So that would be quartz (picks up dolomite) Mica then, I am not sure if this is copper or some other kind of metal, but b/c it is metallic I think it would take longer to form than the thing that I know nothing about (points to hematite). That's my reasoning for that.

M: We can also talk more about these different samples, but I think we will get through and then discuss if you have questions.

V: yeah

M: Okay, so getting back to dating, why do think scientist, geologist whoever may what to date minerals?

V: Well, they make a very long time ago and they make up a huge part of the environment. So, it is important to know, like when earthquakes occur or various natural disasters occur like what's actually happening in those processes and if we can prevent any of that as well as knowing our history in general, like for fossils and things like that, knowing where we can from.

M: How would dating minerals tell us about earthquakes and different things like that?

V: you can see the aftermath of previous earthquakes and when they happened and how they happened and by knowing that potentially being able to formulate future earthquakes and things like that. Also I think early on curiosity was a huge part of it b/c you know they look out and see these huge mountains and want to know how they got there and so obviously the oldest rocks are going to be on the lowest part of it and so I think dating can tell you how old things like that are, like mountains.

M: very good, do you have any other thoughts to add?

V: I don't think so.

M: I can move these off to the side as well.

(Q 17)

M: Alright, so I am going to set 4 samples in front of you again. And do you believe that these are the same or different minerals or mineral, I guess.

V: I think that they're the same.

M: what make you think that?

V: umm the overall feel of them and there are very distinct similarities. Like the edging where they have been broken or the feeling of them, they are all very smooth to the touch. They are all similar in weight. I could check hardness, but I don't know if that would be necessary. Umm, they all seem, this is the only one that stands out to me a little bit (picks up orange calcite). It's got a rougher surface and that its less clear. So, if I were to really say I would say these 3 are the same and this one (orange bumpy calcite) got something that makes it a little bit different.

M: Okay

V: I jumped to a conclusion, before I had really picked this one up, but they all have distinct similarities. But I would say there is something that has influenced the color change. Would be the big thing.

M: Okay so, they can be the same mineral although they are different colors?

V: right, and this one obviously gots something else going on in it, but I don't know. Yeah, they all have, as far as the characteristics of minerals go, I think they are very similar.

M: Okay, so you said that one was more broken up then the others, that besides color, you think they are similar, they have other similarities.

V: Yeah.

M: Alright

(Q 18)

M: And this sample has a lot of lead in it, so after we're done, I'll ask you to wash your hands, make sure before you eat anything.

V: I understand.

M: Ah, so considering these two, again we are back to thinking of concepts, if they were both, and necessarily at the same time, but they could put in at the same time, if they were placed in a fire for about a year, do you think anything would happen to them, or would they react similarly, the same, nothing?

V: do we know the temperture?

M: ah, hot, very hot

V: so, the one that is particularly full of lead (galena) I don't think anything would happen to over a course of a year. Potentially some discoloration

M: now why do you think the lead would make a difference?

V: umm, b/c metals have a higher heat tolerance than whatever this is (holds up the Talc). However, I don't know what this is, so I cannot say for certain that it would be a different outcome than the lead. It feels kind of like glass (the talc). But I know that it's not, just the way this looks to me I feel like something would very change. A physical change for sure in this one. Whether it would be like melting or vaporization. Like I don't know the temperture of the fire either.

M: think hot enough, to do if it was going to cause any change in something, it would so.

V: that is what I'm thinking too. That would be the one to change, if either of them were to change (indicates talc).

M: and you said feel, how does it feel to you? (talc)

V: It's definitely lighter, smooth, you can see the layers again. It's softer than this for sure (softer than galena). And weigh less dense, which is why I suspect something major would change in the fire with this one in the fire than with this. B/c just this little piece has some weight to it, it's lead, so.

M: It is that.

V: So, it would take more for something to happen there, I think.

M: Alrighty, anything else that you want to add?

V: I don't believe so.

M: Okay. Alright, so I think we might be on our last samples.

(Q 19)

M: Alright.

V: More mica you say?

M: Now why do you think that is mica?

V: Umm, it’s got the same flaky look to it and I heard it crinkle when you put it down. So, the same thing happened to that sample (from number 16) when I picked it up.

M: Okay.

V: and then the luster and the translucency of the layers are definitely similar. Is that the outside of where you would find mica, like that is the outside of the rock? (indicating color/texture change). Or does it go like this when you find it? (hold it horizontal).

M: ah, so what do you, so you mean?

V: if this were to occur in like nature, is this what would be facing the observer (indicating the scalloped side, not flat. Does a hand gesture to indicate the mica is surrounded by something.)

M: often, b/c of its structure, not always.

V: right

M: but, umm

V: I didn’t mean to mess you up

M: that’s ok, it depends on how you are looking at a rock or the mineral itself, but often it will, have, it will be kind of like, you’ll see this. (indicating that its flat and can see its layers on the side). Um just b/c it’s how it likes to fit nicely into things.

V: Right, okay. So, this is?

M: So, this is 19. So, can you list any differences between these different samples?

V: um well, let’s have a look**.** Okay. I get this strange feeling that they are all very related.

M: what makes you think that?

V: umm, the overall weight, beside from this one (indicates plagioclase), are very similar. They all have an apparent translucency. Is this at all like cut, or is this found like this?

M: it can be found like that.

V: that's impressive. Nature is interesting.

M: Yes.

V: The other big differences would be like layering. So, I feel that this is a more pure form of a similar substance (indicates qtz).

M: okay, so you are thinking that they are the same or they are not the same?

V: I think, I am not sure where this one falls (indicates plag). I think these two (qtz and halite) and these two would be close (gypsum and muscovite).

M: Okay, what makes you pair them?

V: umm, the apparent layering on this is (gypsum) very thin and goes along the same way that you can see here (indicates mica). It's obviously less flaky, so I think that it might be like a transition, between into this or vice versa into this.

M: Okay.

V: But, I'm not sure that could just be my organizational mind going to work here. But these two have a very similar shine to them as well (mica and gypsum). And these two have the structure that goes along this way (indicates qtz and halite. Showing the flat sides). Verses the lengthwise (indicating the flatness of mica and gypsum). And then I feel that at some point this (halite) could have had a point to it. That could have been similar to that structure (meaning qtz). The only big thing that throughs me off here is that this is a hexagon verses the cube shape. But these two are definitely layered (gypsum and mica).

M: okay

V: so that gives me the suspicion that they are related somehow.

M: in what way, like where they are found or?

V: I think as far as where they are found as well as how they got to where they are found.

M: Okay so like where…

V: So, like this would be, part of a much larger whole (touches mica) and if it were to like broken down or something were to have changed there, it would turn into this (the gypsum) if that makes sense?

M: Okay.

V: umm, but that's just my observations. I don't know, and then this is the one that really stands out (plag), b/c its weighty, it's got some clear parts some less murky parts in it. I don't know if you can see the line structures**.** As well as like the ones that go across when you look at the shine, it's just interesting to me. Umm what am I suppose be listing differences.

M: You are.

V: Here I am trying to put comparisons.

M: this works too.

V: fair enough

M: what you define, what do you see, doing comparisons, you are comparing them.

V: yeah, fair enough. Umm, flakier (mica) heavy (plag) than the rest. Crystal (qtz).

M: so, is this more of a traditional crystal that you have in mind (Qtz) or?

V: Yeah, this is (qtz), if I were, if anyone were to image just like, imagine a crystal this is what it would look like.

M: Okay.

V: So that's why I just kind of call it that.

M: yes. I understand.

V: yeah

M: umm, okay do you have any other, anything to add?

V: nope

M: Alright. I think everything else really, well we have one more that doesn't necessarily have samples, just kind of more again I give you imagery.

(Q 20)

M: Okay so, I'll give you an idea of two kind of different environments. You have environment A and environment B. and so again we are just going back to the same idea of the fire and the different questions like that. If a mineral was buried either one of these environments for a year, would they react differently, would anything happen to them, would they stay the same, does it matter?

V: and this is, would be assuming the same mineral.

M: yes

V: okay

M: we'll just say that they are the same mineral.

V: okay and approximately how deep? Or is it just the concept of buried?

M: I guess the concept of buried, ah still not, very deep, maybe about a few feet down.

V: Okay so, that surface changes aren't clearly affecting it. I would say in environment B, okay, versus, okay, I think that a more drastic change would happen in environment A to a mineral that was buried there, because it seems like somewhere that has a lot more moisture, less plant life affecting it, like it can sit and change along with whatever is in the environment more steadily.

M: okay, what do you mean by plant life?

V: so, environment B has these dry plants that effect a lot of the soil in different ways, search for moisture, the ground wouldn't be very wet is basically what I am getting at here. With, if a mineral were buried there (B), moisture wouldn't really get to it so, the changes that would happen in environment B, would be more, like wear and tear, if that makes sense? Like it would, be more harsh on the mineral, vs changing it like in environment A. You've a good place for things to grow and change.

M: Okay

V: Just conceptually.

M: now wait you were saying here that it would change the mineral (B), but this would not change it (A) A would not change it so much?

V: No this would not change it (B).

M: Oh, that B would not change it.

V: It would change it physically but not that things would combine or react with it, if that makes sense?

M: okay b/c of the lack of plant life.

V: right lack of moisture, plant life, just life in general.

M: Okay.

V: I would think that in more of a deserty environment the minerals that are already present are not open to reaction. They wouldn't do anything more than conflict with a mineral that was buried there. Versus, minerals that are in environment A, that are you know conducive to plants growing, they would be more conducive and able to connect and react with a mineral that was buried there.

M: okay, very good.

V: so that's just my thoughts.

M: thank you, thank you for sharing. Alright is there anything else that you would like to add about these?

V: Nope.

(Q 21)

M: alright so the last couple of questions, we have one more kind of sort of getting down to the concepts of a train, something very heavy were to just stay on top of a mineral for like a year, would that cause any sort of alteration or change to the mineral?

V: I think that one is kind of subjective to what the mineral is.

M: okay, what do you mean by that?

V: so, something as soft as this guy here (picks up the kaolinite) if a train were to sit on top of that for a year, I think it would become powder in the wind.

M: okay

V: versus, a piece of lead, (points toward galena) that would not change at all. Umm, but like I said depending on the mineral, I think that this questions kind of goes back to another one, were it would take a lot of time for that kind of thing to change a mineral.

M: Okay

V: Umm, versus just a year with a train on top of it, so for things that are super dense like lead, I think it would take more weight, first of all. And more time as well, yeah.

M: Okay.

(Q 22)

M: So, when talking about, we have seen different sizes of minerals today and different samples, umm, do you think, why do you think, they can be different sizes.

V: I think just b/c of the concept of mass and volume and density, personally. That's just other science that I can draw off of for things like this. Where you get lead that's just as heavy as the, any of the other samples, but in a much smaller space. I think the reason for that being, to answer the first question, why they can be like that, is just where they're made.

M: what do you mean by…

V: umm, very very deep like bed rock is made for extreme heat and pressure and that being the case it loses a lot of volume but gains just as mush density and mass. Not mass, loses a lot of, no that's correct. It's just as heavy, in a smaller space. And so, to answer the second question, why can the same type of mineral can be large and small. I think that the same thing can apply.

M: okay

V: so, if it's that same mineral that is not in a space that is full of pressure and heat then it has room to grow but is technically the same thing.

M: okay

V: does that make sense?

M: so, it needs less pressure and heat to get bigger? Is that what you are thinking? Okay.

V: and then for things like limestone, where water can carry minerals in and in grow exponentially over time, b/c it has the space to do so. I think that's, also a good reason to why they can be large and small.

M: Okay, very good, anything else.

V: I don't think so.

M: okay.

(Q 23)

M: so almost there so, what do you think minerals are made of in the end?

V: Umm, that is an excellent question. Chemicals I think would be like the smart aleck answer, just like, chemicals and elements.

M: okay

V: What makes up anything, but I wouldn't be able to answer that fully, without some education on the subject.

M: okay, so it seems like you want to go for chemicals and elements and so what makes you kind of pull back?

V: the fact that some of the materials that I have seen are a little more complex than that, it seems to me that it takes more than just that to make a mineral a mineral.

M: do you have any idea of what you mean that it would take more than?

V: to narrow it down to just one or two elements or you know chemicals, would be unfair, I think. Like it takes a very vast number of factors. So that could be 100s or thousands of chemical and elements that I am just not aware of, but I don't know they just seems more complex to me.

M: Okay.

(Q 24)

M: And then last, but not least, how many minerals do you think that you would be able to learn to identify in about a two-hour time.

V: umm, how many minerals are there? And how long would I have, okay so I think that I am confused by the phrasing?

M: so, ah this is more asking about in a typical geology classroom students are given a certain number, they are taught how to identify minerals and then they are given samples and I want to understand how many you feel that if you are instructed on how to do it, how many do you think that you could identify in about a 2 hour time.

V: and then as far as identification would that be like there specific names?

M: their names, so you would learn their different characteristics and you are given a rubric. Umm you use your tools in order to figure out their different, minerals have different characteristics.

V: right, okay,

M: and then based off of that you are given this order of things, and you are like this fits and this doesn't and this fits and based off of this I believe that it's this name.

V: okay, umm in that case, in 2 hours and you have your standard identification kit, I would go anywhere from 25 to 50. Which is a very big span.

M: Okay

V: only b/c I feel that some of these would be much more difficult to identify. And based off what you just said, like what fits and what does not, I feel like the process of elimination could be longer for different kinds of things. And then on the flip side of that, if you know something is something, then it would take a very short amount of time to identify it.

M: okay.

V: so yeah, I think I will stick with anywhere from 25 to 50.

M: alright, sounds good, so would you like elaborate on this question, or any of the other ones, I think it was back to number 10.

V: number 10, it was.

M: and if you know you are not comfortable, or feel like you know, you are not sure about, you know, writing or not writing anything down is fine.

V: I am not confident in my ability's for number 10 b/c I would hate to do anybody wrong, by saying something is a mineral and be completely wrong.

M: you are not doing anyone wrong. So, don't worry about that.

V: no, I think we're good.

M: okay great.

Interview 19

Mandy Manzanares

Thesis 2017-2019

G: Interview 19

2 videos, 38 minutes 29 seconds

Common terms/ideas: 10) Confidence, 50. 11) Past knowledge, properties of a mineral: solid, crystalline, inorganic, definite chemical structure. 12) Just writes them out, halite/salt, graphite/pencil lead. 13) Confidence, Past knowledge, cleavage, perthite, color, k-spar, does not call perthite by name, but describes them as squiggles, grew at or above earth's surface under right conditions, space, chemical conditions, not sure what goes in k-spar beside potassium and what else is in feldspars. 14) Confidence, Past knowledge, yes, resembles kaolinite, maybe clay, but stands by its a mineral, fits requirements: solid etc., soft, flaky, scratch with a finger

nail, doesn't seem fine enough to be silt. 15) Past knowledge, nothing, sunlight on its own not strong enough to degrade, need pressure, temperture, erosion. 16) Confidence, Past knowledge, Interest, yes you can date some, knows can date zircons, can't do by looking at them, nothing sticks out to her to date visually, date to know earth history, hazards. 17) Confidence, Past knowledge, Interest, yes, cleavage, smooth, luster, hardness, didn't test hardness, but from handling them feel she knows, color terrible way to ID minerals, color due to impurities, chemical composition. 18) Confidence, Past knowledge, askes how hot is the fire, feels that year long enough to melt them, depends on melting point, feel talc melt first b/c softer and easier to break bonds, galena has cleavage and hefty and hard so may hold up longer. 19) Confidence, Past knowledge, Interest, Notes, mica first fragile, cleavage, hardness, qtz no cleavage and hardest, luster, order I believe in terms of hardness qtz, plag, halite, mica and gypsum, orders again in terms of luster, mica, qtz, halite, gypsum, plag. 20) Confidence, Past knowledge, less affected in B b/c A has more moisture in the soil, more weathering chemically and physically in A due to water and more plants so maybe roots break apart mineral. 21) Confidence, Past knowledge, pressure of train could cause cracks, breakdown mineral 22) Confidence, Past knowledge, some minerals larger b/c proper environment, space, chemical components, so yes can be large and small but depends on things like space and environment, says depends on time but then says strike that did not mean time. 23) Past knowledge, made of chemicals and lists mineral properties, e.g., inorganic, solid, etc. and how elements are bonded. 24) Confidence, Past knowledge, Interest, if no experience 10-12, her mineral lab was 2 weeks 15 minerals per week, feels 12

minerals in 2 hours as long as they are distinct, e.g., distinct streak, hardness, has conchoidal fracture.

Intro: starting with background and then mineral questions

1) 1996

2) Female

3) Suburb near small town

4) 4

5) HS: Other: Geography; College: Geology, Oceanography, Meteorology

6) HS: Biology, Chemistry, Physics; College: Chemistry, Physics

7) College: Calculus 2

8) Earning Earth Science M.A.

9) Yes

(Q 4)

V: Still I want to say that my confidence level is a 4

M: that's okay

(Q 5)

V: would that be where I add another subject that I did in high school? That was kind of scienceish.

M: yeah. Which one did you do?

V: geography.

M: I did that too.

(Q 7)

V: and I just mark the highest one?

M: yeah, I have also people filling the rest, but you can’t really take calc 2 without…

V: yeah

(Q 8)

V: and onto the minerals…

M: almost, just a couple more questions. And if you just want to say that you are getting you masters, that’s okay.

(Q 10)

M: so, for number 10 if you just want to list a few and just say, but you can always say a number, how many that you think you can name.

V: so, just give a number, like I think I could name this many minerals off the top of my head?

M: yeah, and if you want to name a couple, but I figure that you can name quite a few. If you give me a number that will be fine.

V: giving a number I would say 50, b/c that’s what we had to do in our mineralogy class.

M: around 50 or so.

V: around 50 minerals, by name only.

(Q 11)

V: do you want me to talk about all that now.

M: so, yeah for number 11, it’s yeah, it is just anything you know to be true about minerals.

V: well, I know that they are solid, crystalline, inorganic, definite chemical structure.

M: so, the properties, anything else?

V: nope

(Q 12)

M: and for number 12, name whatever kind of pops in your head. So, if you are ready for 13 that's when we start with samples.

V: yup.

(Q 13)

M: you are welcome to draw of the minerals as you like, but for number 13 in particular I would like you to draw this one. Either on here or on your paper (interview sheet or empty sheet) either way. and the observations you have. I am providing color pencils. And for this or for any of the other samples, you are welcome to use, this is a mineral id kit that we have all the students in class. A streak plate, Mohs hardness scale, nail, magnet, glass plate, qtz crystal, penny and a geologist hand lens/ magnifying glass.

V: drawing is hard

M: did you say you're drawing a sword?

V: drawing is so hard.

M: okay. So, I noticed these jagged lines, what are you depicting here?

V: so, I'm trying to show, that all of the edges aren't even, b/c there are 2 planes of cleavage in this one. And I was trying to show that the top and bottom would be one cleavage surface and one of the other sides, so probably here and on the back, but I don't think that I am representing that too well in the drawing.

M: I also noticed that you made line, what are?

V: yes so, these squiggles on the surface, they are only on this side (Perthite) and not on any other surface, so I just put them here. And as far as observations, the color, cleavage.

M: what is it about the color that you notice?

V: it's like a salmon, so a lightish pink, yeah. Do I have to name it?

M: if you want, anything that you observe or know about it.

V: its potassium feldspar.

M: okay, any other observations that you have? How did this mineral form?

V: it grew in let's see, so it had to have sufficient space and the right chemical conditions. So, I don't know what the chemistry of what it is exactly, but potassium at least and like the other things that go into feldspars, all had to me present and in like the right quantities and it would start growing?

M: would it be in any particular location?

V: what do you mean?

M: well, you are saying that it's growing, is there any particular environment that you are thinking of?

V: yeah, at or above the earth's surface.

M: alright so, any other ideas on formation or observations you have about this sample.

V: no, not really.

(Q 14)

M: so, this our next sample for 14. And is this a mineral and why or why not?

V: yes, I think so, at least I think it is. Yes, we are going to go with yes.

M: okay, what makes you say that?

V: b/c it closely resembles the mineral kaolinite, so, or is it, no it's a mineral. Yes. I am standing by that. And as far as I know it fits all the requirements to be a mineral, solid, inorganic, it is made of only one thing, while rocks are made of multiple minerals, this is all there is.

M: so, you said it closely resembles a certain type of mineral, what is making you say that?

V: the softness, like the extreme softness, not just being scratched with a fingernail, but flaking off, like this (shows powder). And the texture of the particles that come off so, they don't really feel like either too fine to me a silt. I guess they could be a clay, but I still stand by it being a mineral.

M: very good, anything that you would like to add about this sample? About why or why not, you think it's a mineral? (tastes mineral) True geologist.

V: yeah. No.

M: okay

(Q 15)

M: so, kind of just brain storming with this one, what would happen if I placed a mineral in sunlight for a year and why?

V: just sunlight?

M: umm humm.

V: nothing. Just the light not the heat or anything else? Just if we put it in the window?

M: yes, if we put it in the window.

V: not a whole lot would happen to it. b/c there's, b/c sunlight by itself wouldn't or shouldn't degrade most minerals, b/c that is just light and nothing else, like heat or pressure or like erosion. Or anything else that would be changing the form of the mineral.

M: so, you are saying that you would need more?

V: yes.

M: any other ideas of sunlight do's or don'ts.

V: apart of this question of the next question?

M: no for 15, anything else to add?

V: no.

(Q 16)

M: so, for this question we have 4 different samples. So, the first part of this question is can scientist tell how old minerals are, and do you think that's possible.

V: yeah, with some minerals you can tell age by using chemistry. And I know that zircons at least can be age dated, other minerals not sure. I think it is a select few. So, yes sometimes.

M: okay, if you think it is possible by observing these samples do you think you could order them from youngest to oldest?

V: no, not looking at these samples, b/c just by appearance there isn't anything about any of these that make them seem, like nothing that is popping out that is indicating age. Just based on their physical appearance. That's pretty though (Chalcopyrite).

M: why might scientist want to date minerals?

V: b/c you would be able to have the age of formation for the environment that the mineral came from. You would be able to reconstruct geologic history and help with mapping surfaces and other fun things like that.

M: why would that be beneficial?

V: b/c, should I be writing this down?

M: If you want to answer mostly verbal, that's fine.

V: okay. Yeah, like safety reasons, just to know the age and strength, reactivity of locations that you are planning to build or develop. And if you are trying to pinpoint the ages of specific geologic formations or activities that created, like say the rocky mountain range or stuff like that.

M: okay, anything that you would like to add to 16 about dating or ordering?

V: I feel good.

(Q 17)

M: so, I have 4 samples again. And are these the same mineral?

V: yes

M: okay, what make you say that?

V: so, they seem to have the same number or cleavage plains, so like 3. Although, (looking at green) *I'm not going to look at this one,* I am not feeling very good about that one. So, 3 and the same angles, so they are smooshed in the same way and they seem to have the have the same luster. So, I would say yes.

M: luster meaning what?

V: like being *near* the light, the way the surface reflects light.

M: so, can minerals be the same, but come in different colors?

V: yes, b/c color is a terrible way to identify minerals.

M: do you have an idea why minerals might be the same, but different color.

V: b/c impurities can affect the color of a mineral, so like qtz and halite and calcite can look orange, if they have like iron or something staining them. Like it all depends on what extra thing is in them. Chemical composition of a mineral. It's pretty (orange).

M: so, any other ideas on why these are the same?

V: I think, they have similar hardness's, I didn't test all of them, but just by handling them, I think.

M: okay, so anything else?

(Q 18)

M: so, what would happen if these minerals were placed in a fire for a year and why?

V: how hot is the fire?

M: think of a normal fire, a normal kind of campfire.

V: for a year. I think that should be enough to melt them. I don't know what the melting point of these are, but for a year. Yes, I think.

M: would they react differently or the same?

V: like would they both melt?

M: yeah, or at different times? Or would they…

V: I don't know if they would be too different. My guess is that maybe this one (talc) would melt first, or break down first, b/c it's softer, so maybe the bonds aren't as strong in this one (talc). As compared to this guy over here, which not only has cleavage, but also is kind of hefty and hard so, maybe it would hold up a little longer.

M: any other, things that would happen in a fire or how they would react similarly or differently?

V: uh uh.

M: okay.

(Q 19)

M: so, these are our last actual samples. So, between these 5 samples, please list any differences between these minerals that you can.

V: okay, in any particular order.

M: uh uh, just whatever you observe first.

V: so, this one (Mica) has, is fragile only one plain of cleavage, pretty soft. This one (halite) has multiple plains, 3 plains, 4 plains, 3 plains, harder than this guy (than the mica). This one (qtz) does not have cleavage and would be the hardest. And this one (plag) also has cleavage on two plains. So, I will order them like this, none, 1, 2, 3 (qtz, plag, halite) and also one (gypsum, sets by mica) and it is also pretty soft. Yeah, so does that work? I know I did some similarities too but…

M: yeah, that's fine. So, you are noticing cleavages, how hard they are, anything else any other differences?

V: I guess you could also do luster, so again how they reflect light.

M: okay

V: with this one being the most reflective out of all of them (mica) 2nd, 3rd 4th last (not sure of order but looked like mica, qtz, halite, gypsum, plag). That's it.

M: alright.

V: where did you get these samples from?

M: the rock room, the one upstairs and downstairs.

V: it's so thick (mica)

M: yeah, when I saw it, I was like mine.

(Q 20)

M: for the next question, what would happen if a mineral was buried for a year in environment A vs. environment B.

V: buried, how far, how deep.

M: so, not very deep, more like a couple feet under.

V: ok so environment A, or environment B seems to be more arid then environment A so, I guess if there is any weather or like weathering away of the surface. I would expect it to be in A b/c there is more water in the soil for that to happen and I would kind of expect B to be less effected.

M: okay.

V: generally

M: so, more like wearing away the soil.

V: like there is water, moisture in the soil that could facilitate breaking down the mineral while it is buried. And then yeah, probably more erosion and activities, similar activities in A then in B.

M: okay, and so the water itself would have an effect on the mineral?

V: yes.

M: any other things, differences that might happen?

V: I guess it seems like there is more vegetation in A maybe. There is more grass, so maybe the roots could also play apart.

M: okay, in what way?

V: like as the roots grow down onto or around the mineral, it would break it apart.

M: okay, any other ideas?

V: nope.

(Q 21)

M: so, what would happen if a train stayed on top of a year and why?

V: it's always a year. The train, I guess the weight of the train would cause some cracks in the mineral over time, just from the constant pressure. And I think that's it.

M: so, I would be breaking it down?

V: umm humm.

M: okay, any other ideas?

V: (must have shaken her head)

(Q 22)

M: so, for 22, why are some minerals larger than other minerals?

V: b/c larger minerals have more of an ideal environment to grown in, so more of the chemical components that they require for their growth and more space to grow and expand into. And yeah, the same mineral can form large and small versions of itself b/c of that, so if it's like best case environment, lots of space, lots of time, can grow really big. And the opposite if it is confined or compressed or has to grow around other things, then it would be pretty small.

M: okay, so time, you said time?

V: I did not mean to say time.

M: okay

V: strike that

M: okay so it's more about the environment it's in and what's around it?

V: umm humm.

M: anything else one why they can be big or small?

V: uh uh.

(Q 23)

M: what are minerals made of?

V: chemicals

M: can you expand?

V: didn't I write this down somewhere else (looks through interview) they are solid, inorganic, definite chemical structure so, their made of individual, or bonded, elements that are bonded to each other in specific order and number.

M: okay, anything?

V: uh uh

M: okay

(Q 24)

M: so, 24 is just more of a lab setting so if you're a student or thinking back to when you were a student, if you are provided the material that we provided, how many minerals do you feel that you could identify in 2 hour and why?

V: so, 2 hours one time with no prior experience. I think the most that I could do would be like 10 to 12 and if they have like distinctions between them.

M: okay

V: so, I am thinking back to my intro lab, when we did minerals. So, we also did minerals for 2 weeks, I think we had to do, was it like 30 of them, it was like 15 per lab. Or somewhere about there. And I remember that I got.

M; 15 or 50?

V: 15 per lab. So, like an intro class, not a mineralogy class. So, I think the ones I got first were pyrite, b/c it has a distinct appearance and when you streak it does, like its streak is very different then whet you expect. Or at least what I expected. So that one was easier for me to remember. Qtz b/c the conchoidal fracture and the hardness is easy to keep track of, but things like calcite and halite. I remember them individually, but it was hard to tell the difference between the two of them at first. And then when we started to get into things that really didn't look too special or distinct at all. Like pyroxene and chlorite, that took a while. So, I would comfortably cap myself at 12 minerals in 2 hours, if you can easily tell the difference between those 12.

M: okay. Anything that you would like to add to this or any other questions?

V: no, this was cool.

M: alright, well thank you.

Interview 24

Mandy Manzanares

Thesis 2018

P: Interview 24

1 video, 34 minutes 4 seconds

Common terms/ideas: 10) Confidence, Prior Knowledge, Notes, 15 then changes answer later and writes 30. 11) Confidence, Prior Knowledge, describes mineral properties: solid, crystalline structure, etc., mentions groundwater, formation depends on temperture and pressure conditions, conditions/compositions of solutions, make up rocks. 12) Prior Knowledge, salt, gypsum -building materials, this pencil, metals in everything, roads/ concrete full of them, they are everywhere (all are written on interview sheet). 13) Confidence, Prior Knowledge, Notes, points out the evolution laminae also calls it perthitic texture but not sure how formed, discontinuous series, doesn't have the right color of pink, mentions Bowens reaction series, formed lower temperture, high silica magma, high in potassium, contains potassium and sodium- see with perthite, not a calcium rich feldspar. 14) Prior Knowledge, asked if needs acid, believes a rocks b/c made of many little crystals and

a mineral should just be one thing. 15) Prior Knowledge, depends on mineral and crystal structure and thermal properties, could expand and contract, mineral alone not as much and many minerals in a rock that could be affected as expand and contact. 16) Confidence, Prior Knowledge, can date through radiometric dating and can look at how weathered a mineral is, but not as reliable, would not date them, dating is one of the most important thing to geology, can tell us order of what happened and if not in order we expect then something happened to disrupt order. 17) Confidence, Prior Knowledge, wants acid right away, believes all have the same chemical composition, they might have different structures, believed could be different polymorphs or different structure of the same chemical composition, and considered the same mineral, believes same mineral because all are shiny, have similar cleavage, soft, green maybe fluorite but feel it has the wrong cleavage, recognizes orange calcite form somewhere, color not a reliable indicator, color could be due to trace elements, impurities, polymorphs. 18) Confidence, Prior Knowledge, doesn't feel hot enough to melt maybe the talc would melt, but doesn't think so, ID's the talc, maybe get an oxidation char, spoliation, thermal properties like in answer to question 15 so expansion and contraction, make more susceptible to weathering, does not feel like the temperture change would have an effect on these minerals concerning dating rocks and having the "clock" reset, talc would react more to the fire then galena. 19) Confidence, Prior Knowledge, Mica has platy structure, and it is the platyest of all of them, gypsum is a little bit platy, plag and halite have pretty pronounced cleavages, plag has non-90-degree cleavage and similar texture to first sample shown in the interview, halite is salty, soluble, and has cubic cleavage qtz has

a crystal structure and not a cleavage and has conchoidal cleavage, all have like a glassy, shiny luster, all a similar color, different hardness, clarity differs halite and qtz are a bit more translucent. 20) Confidence, Prior Knowledge, A more chemical weathering less erosion, B more physical weathering could have more erosion and transport due to possible flash floods and variety in temperture so maybe more frost wedging and spoliation. 21) Confidence, Prior Knowledge, depends on mineral, but trains on minerals all the time and nothing really happens, maybe deform, compaction like see on roads, if many minerals together in a rock possible stronger than one mineral alone, like a clay mineral would be crushed and deformed. 22) Confidence, Prior Knowledge, some minerals are just inherently larger or smaller based on their chemical properties, they may have the propensity to be larger or smaller, can be large or small based on conditions of its formation e.g., slower cooling magma, space, the type of solution, and the nuclei that is causing the precipitation might also impact the form, yes can be big of small, based on the temperture and how quickly they are cooling and then sort of the environment, which they are forming. 23) Prior Knowledge, "they are just made of elements, just specific chemical formulas, so they are just chemical compounds." 24) Confidence, Prior Knowledge, first says 10 then 5-10, takes a while to build skills and knowing how to identify minerals, depends on minerals and how easy they are to identify.

Intro: I start by explaining the layout of the interview, with background and then mineral questions.

1) 1984

2) Female

3) small city (town)

4) 5

5) College: Geology

6) HS: Chemistry, Biology, Physics; College: Physics, Chemistry

7) College: Calculus III

8) Geology

9) Yes

(Q 10)

M: so, for 10 if you just come up with a number, that works.

V: okay, I don't know if it's true, but 15. (Writes 30)

(Q 11)

M: and anything that like come into your mind.

V: I guess I should start *with ground water*.

M: so, it looks like you're, describing like the properties of them and kind of how they are formed.

V: Umm, humm

M: yeah.

(Q 12)

M: and when you are ready 13 is when we start having samples.

V: okay, I think I'm ready.

(Q 13)

M: so, feel free to draw any of the other minerals, but for this one in particular if you could draw what you see either on this sheet (plain paper) or on here (Interview sheet). I have also provided color pencils, if you would like to use these. And all volunteers are also provided with a mineral test kit, that you are welcome to use, this is what geology 100 students are required to purchase. A Mohs hardness scale, qtz crystal, steak plate, penny, nail, magnet, hand lens, and a glass plate. Oh, that is separate (referring to question 14).

V: oh separate, sorry.

M: yeah, that's okay. So, you are noticing the texture on the side?

V: umm humm, you can actually see those too, the inclusions.

M: what creates that texture?

V: do you want me to say right here (indicating paper).

M: yeah and you can also say if you want.

V: so, it's a, I forget what it's called, I think it's exsolution texture from… I don't remember how to make this guy. I notice that it is not continuous. So, that the potassium and sodium can't exist together, and the solution series, so I forget what it, but it's like it's discontinuous b/c it's a discontinuous series, based on the composition. And then, and so how much do you want me to like explain what I'm doing? Versus, what I wrote?

M: as much as, you like.

V: okay

M: so, it looks like your noticing the texture.

V: it has a cleavage here, so I just did an angle for the cleavage. And it has a blocky on, pretty much all sides, but especially certain sides are blockier. And then it has this, I think it is perthitic texture. That this, texture where you have these streaks. And it's a pink color. And I don't have the right color pink that I want.

M: yeah

V: and then it has to do with, so the formation. How does this mineral for? So, the formation, would be from Bowens reaction series, that this would be a low temperture mineral. I don't, if you want me to do the whole thing, but low, basically a low temperture, from a silica rich magma, would be, so it's cooling, from the silica rich magma. At a pretty low temperture. And then, that's it, I think.

M: okay, anything else you would like to add, or we can move onto 14?

V: just that it's, from the texture, I and the color I know the composition of this mineral.

M: okay, what is it.

V: so, its potassium, I think it's a potassium, sodium, with this perthitic texture. Either that or I am miss diagnosing it, and it's just a k-spar. But it's definitely not a calcium rich feldspar, it's a potassium rich feldspar of some variety.

M: alright.

V: okay

(Q 14)

M: 14 is a new sample.

V: oh, it's a new one?

M: yes

V: okay.

M: so, is this a mineral and why or why not?

V: I don't need any acid?

M: no

V: I think it's a rock. So, composed of a mineral. b/c it has small particles that are all together and technically minerals should be its own individual thing, with a specific crystal structure. So, I think it is a rock composed of many little pieces of a mineral.

M: Okay.

V: do I have write that.

M: no, if you want to, but otherwise you don't have to, so.

(Q 15)

M: so, 15 we do not have a sample, it's just thinking, what would happen if I place a mineral in sunlight for a year and why?

V: just any mineral?

M: however, you think about, yeah so, yeah it could be any mineral.

V: well, minerals have different properties. Thermal properties, so it could expand and contract, but if it only one mineral by itself it wouldn't necessarily do much, but if it had, different minerals in a rock, composed of different minerals, you could actually have, you could have fracturing from different thermal properties, expanding and contracting.

M: okay.

V: that's all I can think of.

M: would all minerals do that, or would certain ones react differently.

V: certain ones would have different properties so depending on things like the crystal structure and how much it changes it's temperture.

M: okay, anything else that you would like to add for 15?

V: uh uh.

(Q 16)

M: so, 16 we got 4 different samples, so can scientist tell how old minerals are? And if possible, do you think that you could order these, in a youngest to oldest?

V: okay so, so yes scientist can tell how old some minerals are with things like radiometric dating techniques. And then you could use some other indicators like weathering, however, the fact that somethings weather more easily than others would make this very confounded. Such that, I probably could not order those, and I will not.

M: okay

V: oh, why might scientist want to date minerals? So, you can tell how old other things are based on the relative location of them. And so, we would expect a certain order and so if things are out of order then we know something like tectonic might have happened, or we might be interested in something else that we can't date. And so, we can date the minerals in the rocks, by association and that tells us the sequencing of anything geologically. So, it is like the most important thing too in geology.

M: okay, figuring out sequencing. Anything else that you would like to add?

V: to that one no.

M: okay.

(Q 17)

M: so, we have 4 samples again. And are these the same mineral.

V: I don't get any acid, it's not fair. I think so, unless one is fluorite and tricking me. But I think they are all calcite and if I could confirm that with a reaction, then I would know b/c they would all have the same chemical composition. They have, they might have different structures, but they are, there could be different polymorphs or different structure of the same chemical composition, which we consider to be the same mineral. So, I believe these are all polymorphs of the same mineral. So, they all have the same chemical composition and so they would all have the same reaction to HCL, if I were to have it.

M: what makes you think, without the acid, why do you think they are the same?

V: the luster, so they are all very shiny and some of them have a very specific cleavage to them. That is this funny angle, so they are not actually cubic. So, they don't have 90-degree angle. And then this one is weird (orange), but I have seen this exact, very similar one before, and I believe it to be calcite based on previous experiences. This one has funny purple color, looks a little bit like fluorite, but I don't think that fluorite has the same cleavage. Also, this one has a fluorite color (Green), but I don't think it has a fluorite cleavage. They are all probably pretty soft, yeah so, I can scratch them all, so they are pretty soft, based on the hardness.

M: so, they all do react to acid.

V: okay

M: can, so why, or can a mineral come in different colors?

V: yeah, so I can't think of any mineral that is exclusively defined by a color in fact, so it is just sort of a property of the mineral, or different polymorphs of the same mineral. It is probably the least reliable indicator.

M: what could cause the difference in the colors?

V: probably different trace elements, that maybe sort of impurities in the chemical formula.

M: okay, anything that you would like to add about these?

V: no

(Q 18)

M: so, here are 2 more sample. And what would happen if these minerals were placed in a fire for a year and why?

V: so, cause it, the temperatures are probably not high enough to actually cause the minerals to melt, so I think this is talc or something (talc). I guess it could be gypsum, but I think they could just get a char, like an oxidized char and they may, their maybe more of an issue with, the thermal properties. Like I said in 15, so if you get it hot enough like you could have like a, *spoliation* on the out edge of the mineral. But I do not believe that a fire is hot enough to actually melt any of these. Maybe, this one (talc), but I doubt it. I would have to know more about the temperatures of fires. And so, I think it would have more to do with the thermal properties changing and that could affect the weathering. Probably more than anything. And then it could also just break down some of the chemical structure and make them, more easily weathered. But I wouldn't expect any actual melting. And these ones I don't, these ones it probably doesn't matter, but if you had minerals that you wanted to date with, like a low temperture thermal chron. Which you couldn't use on these, but if they were, then you could actually reach temperatures were that would be affected. So, like apatite or thorium or helium, it is pretty low temperture, even *recent* tracking, you might actually like reset some of the low temperture clocks. So, then you wouldn't want to use with dating. But I don't think you could do that on either of these any way. So, wouldn't matter.

M: it seemed like you were thinking maybe they would react differently?

V: the two of them?

M: yeah.

V: I mean this one is metallic (galena) so, I don't actually know the temperture ranges for these formations, but I think this one is probably lower temperture (talc). So, that perhaps would have, would be more reactive (talc) to, I don't think that it would melt, but maybe breaking down. But that is just a guess, I don't really know specifically what the temperture change would do for these ones.

M: okay, anything else that you would like to add.

V: no

(Q 19)

M: so, these are last actual hand samples, so you have 5 different minerals. And please list as many differences between these as you can.

V: can I just say them and not write them?

M: umm, humm.

V: so, this one (Mica) has a different texture, or platy structure, and it is the platyest of all of them. This one also has (gypsum), a little bit platy. It is kind of weird looking, but it has those horizontal plains. So that's a main difference between these two (gypsum and mica). This one has, these 2 have (plag and halite) pretty pronounced, other, multiple cleavages. Whereas these 2 (mica, gypsum) have more of the plainer cleavage, this one has a, this is salty (halite) and has cubic cleavage. And this one (Plag) and has the non-90-degree cleavage, so the cleavages are different. And then this one (QTZ) has a crystal structure and not a cleavage. This one would be a conchoidal cleavage, so the cleavages are different in these (all). And even these ones (gypsum and mica), this one is much platier (mica). The luster, they all are kind of a similar luster. They are sort of the glassy, shiny luster. They are all a similar color. The hardness would be different, and they might be different on different cleavages. This one would be really soft one way, but harder the other (Mica). I think this one is softer (gypsum) and this one (qtz) is going to be harder. This one (halite) is going to be pretty soft. The hardness is different. This one would probably dissolve in what (halite) so the solubilities are different. The clarity, so you can kind of see through this one (halite) and so these two (halite and qtz) are obviously a little bit more translucent. And this one also has that same kind of texture that we saw in the first sample. Yeah, I think that's it.

M: okay

V: oh, and this one has a very obvious crystal structure (qtz), I guess.

M: anything else?

V: no

M: alright.

(Q 20)

M: alright so, what would happen if a mineral was buried for a year in environment A vs environment B?

V: a specific mineral or just any?

M: any, any mineral.

V: okay so that, environment A looks like it's moisture, so it has more water, so you would have an increase in chemical weathering. So, then it may break down quicker, though chemical weathering processes. Were as environment B is more arid so you might have more physical weathering in that environment and so you might have more changes in temperture that might fracture the rock, frost wedging, spoliation, so I think the weathering would be different in each of those and the transport processes would probably be different too, when they broke down.

M: meaning what?

V: so, if this environment (A) you probably don’t have, you probably have slower processes, this is a very diffusive land scape, so you have very slow processes moving the materials there, after they are broken down. While as in environment B you may have things like flash flooding that may like move out, so like erode faster. So, the chemical weathering vs. physical weathering are different as well as the erosional ranges.

M: okay, so it would just kind of depend, some may have. They both seem like they would be acted upon by the elements in each, in each place.

V: I just think it would be more chemical weathering in A and more physical weathering in B. and the type, the frequency of transport processes would be very different.

M: okay anything else?

V: no

(Q 21)

M: 21, what would happen if a train stayed on top of a mineral for a year and why?

V: A train, on top of a mineral for a year. I think it really depends on the mineral. So different minerals would have different strengths and they may deform under the weight of a train, but if you think about, trains are on top of lots of minerals all the time and not much is happening. They are getting compressed, so it really would depend on the strength and the properties of the mineral. But I mean trains are on top of minerals all the time right now.

M: yeah, that's true. So, you are saying it kind of depends, could it cause anything to happen or not so much?

V: Well, you can cause it, so I guess, it sort of depends if we are talking about minerals or rock that are made out of minerals. So like clay minerals, like it is not an isolated mineral, but kind of compression from a train would cause deformation of specific types of clay minerals, that could be problematic. And then, once minerals are not as strong, could fracture under the weight, so you may just have some degradation of whatever the train was on. Compaction. I think it would be similar to like what we see on roads. So that certain places are not very good for the infrastructure depending on the composition.

M: umm, humm. Anything to add.

V: (must have shook head)

(Q 22)

M: why are some minerals larger than some minerals?

V: some minerals are just inherently larger or smaller based on their chemical properties, they may have the propensity to be larger or smaller. So, there may just be over all differences. A specific mineral maybe large or small based on the conditions of its formation. So, if it is coming from a magma, and is cooling from a magma, then time it takes to cool would dictate the mineral size. As compared to a slow cooling magma would produce, large crystals. And a quick cooling magma would be small crystals, but then likewise in other types of crystals that are forming from solutions. There would be other things related to the type of solution and maybe even the nuclei that is causing the precipitation might also impact the form. And then also the space. So, you have a big space to crystalize in vs a smaller space that's more compressed. That would also impact the crystal form. Or the crystal size.

M: okay, so then can the same type of mineral form both large and small minerals?

V: yes, just based on the temperture and how quickly they are cooling and then sort of the environment, which they are forming.

M: okay, any other ideas about size?

V: no

(Q 23)

M: 23 what are minerals made of?

V: they are just made of elements, just specific chemical formulas, so they are just chemical compounds.

M: okay, anything else, any else to add?

V: uh uh.

(Q 24)

M: 24 is for a kind of laboratory setting, so either thinking about when you were studying minerals or the now, thinking about how many students, how many minerals a student could figure out. How many minerals do you feel that you could learn to identify in 2 hour and why?

V: So, like new minerals.

M: even if you are thinking about when you started doing this yourself.

V: 10

M: about 10

V: b/c you don't know any of the properties, you first have to learn how to identify the properties and then, well yeah, I just think that it would take a really long time to learn the different properties that you need to know how to use. So, like a skill building and the on top of that, going through the actual process of identifying them takes a long time if you are doing it properly for the first time. And the there is the *memorization* piece, and I am really bad at memorizing things myself so, I think that it actually take like many different steps to get to identifying new minerals, that 10 maybe even be high, if you are to actually remember them long term.

M: okay, so about 10, so 10.

V: 5 to 10

M: 5 to 10. Why a range?

V: b/c some people are really bad at memorizing things too. So, like I am really bad at memorizing and then if you, some people might be able to look at them once, know them quicker.

M: alright…

V: and it also probably depends on which minerals they are, so like some would be easier to identify and memorize and then maybe they are more consistent. They don't have polymorphs; they are always the same polymorphs the same shape. And then other minerals are really ambiguous and hard.

M: okay

V: so, if you have like ten of those it would be impossible.

M: yeah, anything else that you would like to add to 24 or any other question.

V: the only other one, I think I made up a number of how many minerals I could identify, and I said 15, which is probably not true. I probably know at least 30. I don't know I would have to; I don't remember what I remember.

M: yeah, start making lists. Alright.

V: that's it.

M: thank you.

V: you're welcome.

APPENDIX C

VOLUNTEER DRAWINGS

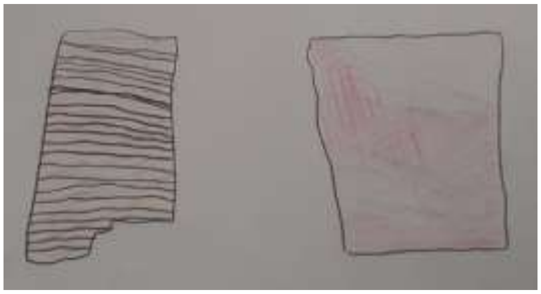

Figure C. 1: These images are from Interview 2, a novice's interpretation of the potassium feldspar sample.

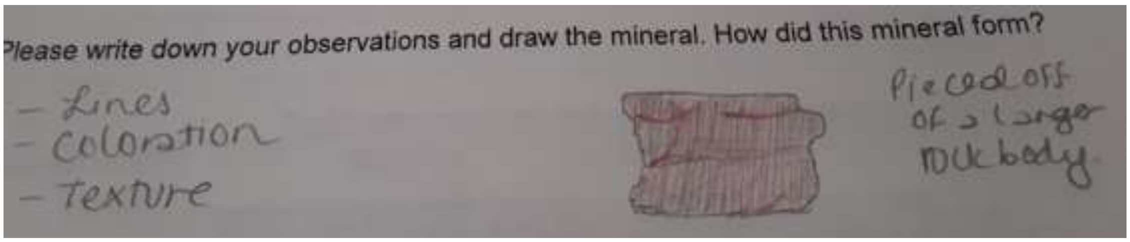

Figure C. 2: These images are from Interview 4, a novice's interpretation of the potassium feldspar sample.

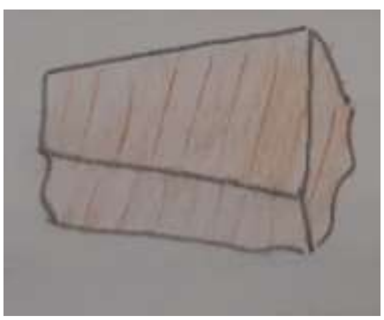

Figure C. 3: This image is from Interview 5, a novice's interpretation of the potassium feldspar sample.

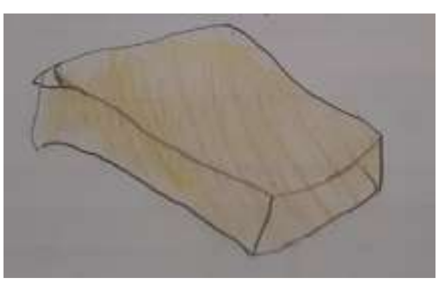

Figure C. 4: This image is from Interview 6, a novice's interpretation of the potassium feldspar sample.

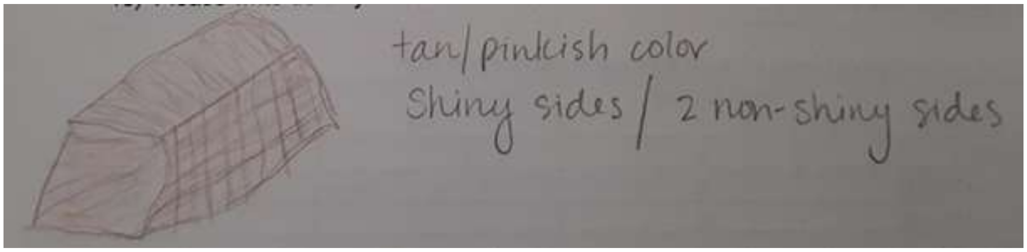

Figure C. 5: These images are from Interview 7, a novice's interpretation of the potassium feldspar sample.

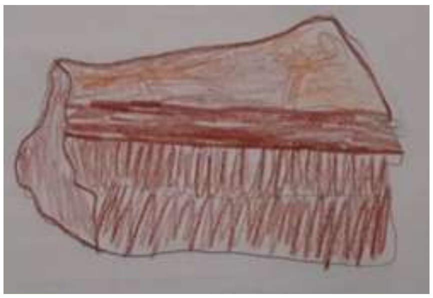

Figure C. 6: This image is from Interview 8, a novice's interpretation of the potassium feldspar sample.

Figure C. 7: This image is from Interview 9, a novice's interpretation of the potassium feldspar sample.

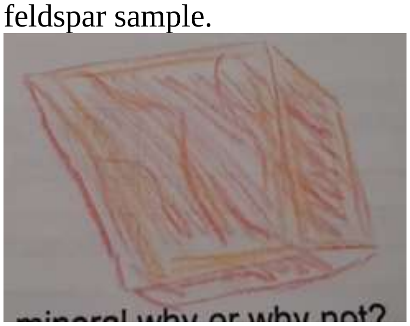

Figure C. 8: This image is from Interview 10, a novice's interpretation of the potassium feldspar sample.

Figure C. 9: This image is from Interview 11, a novice's interpretation of the potassium feldspar sample.

Figure C. 10: This image is from Interview 12, a novice's interpretation of the potassium feldspar sample.

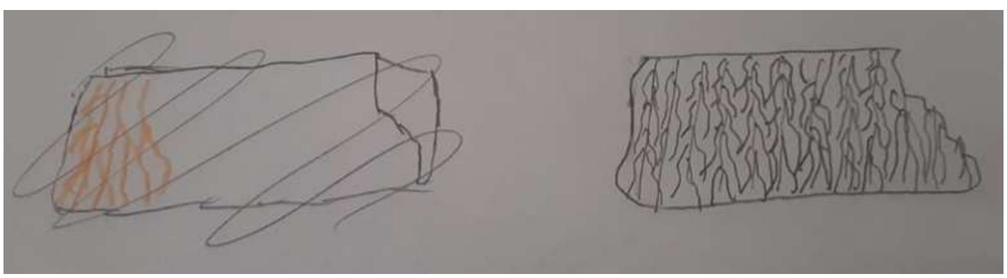

Figure C. 11: These images are from Interview 13, a novice's interpretation of the potassium feldspar sample.

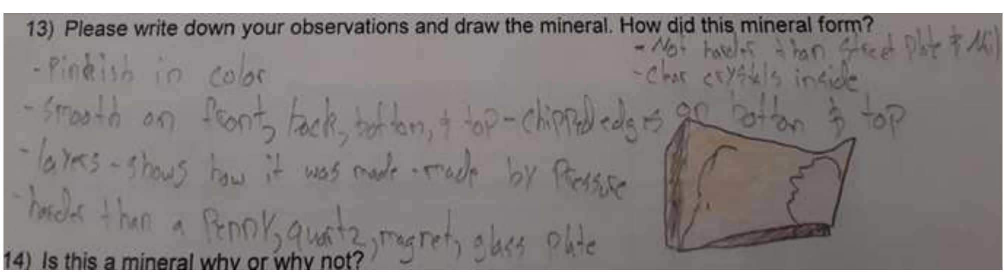

Figure C. 12: These images are from Interview 14, a novice's interpretation of the potassium feldspar sample.

Figure. C 13: This image is from Interview 15, a novice's interpretation of the potassium feldspar sample.

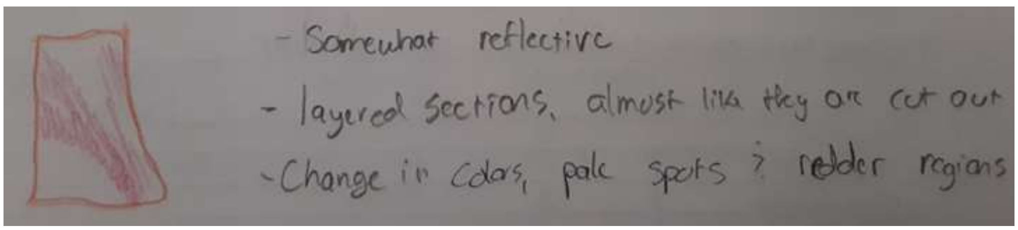

Figure C. 14: These images are from Interview 16, a novice's interpretation of the potassium feldspar sample.

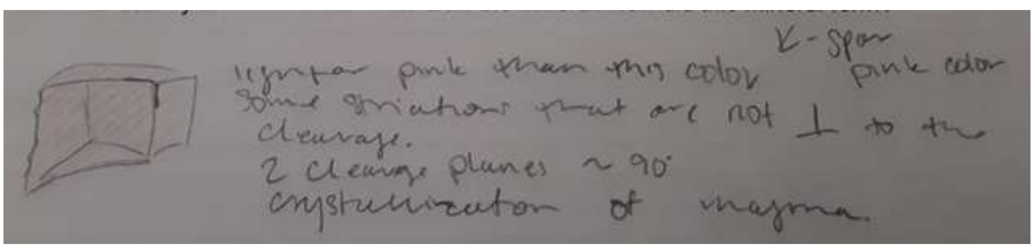

Figure C. 15: These images are from Interview 17, a graduate teaching assistant's interpretation of the potassium feldspar sample.

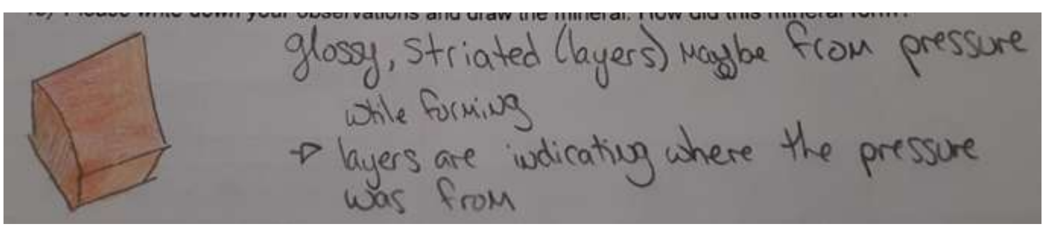

Figure C. 16: These images are from Interview 18, a novice's interpretation of the potassium feldspar sample.

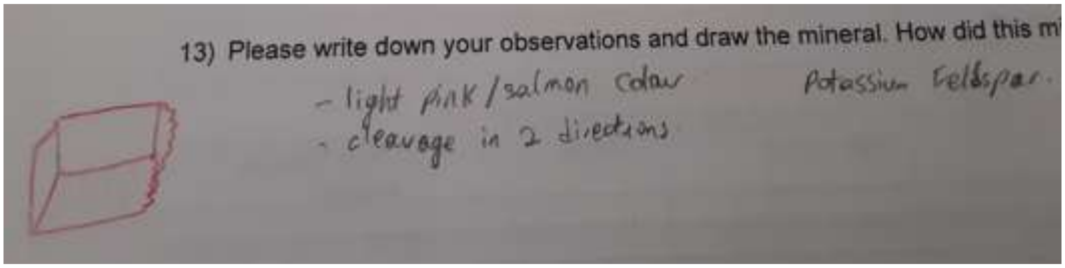

Figure C. 17: These images are from Interview 19, a graduate teaching assistant's interpretation of the potassium feldspar sample.

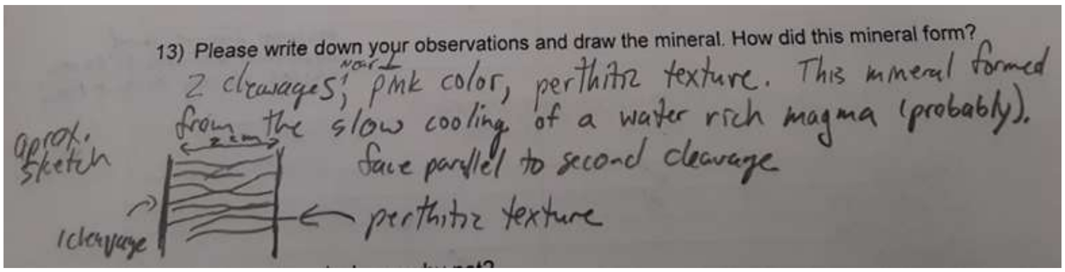

Figure C. 18: These images are from Interview 20, an Earth Science professor's interpretation of the potassium feldspar sample.

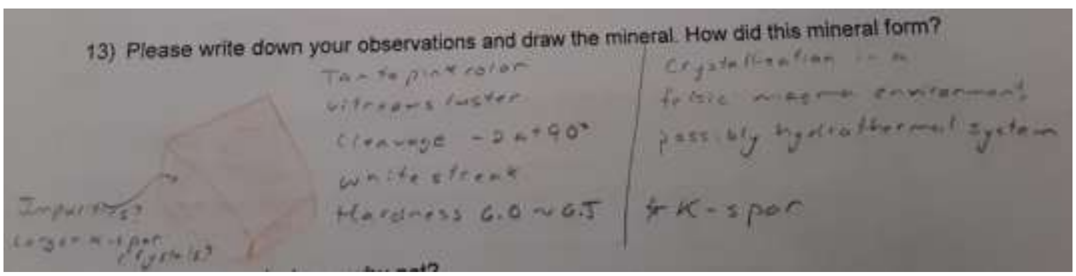

Figure C. 19: These images are from Interview 21, a graduate teaching assistant's interpretation of the potassium feldspar sample.

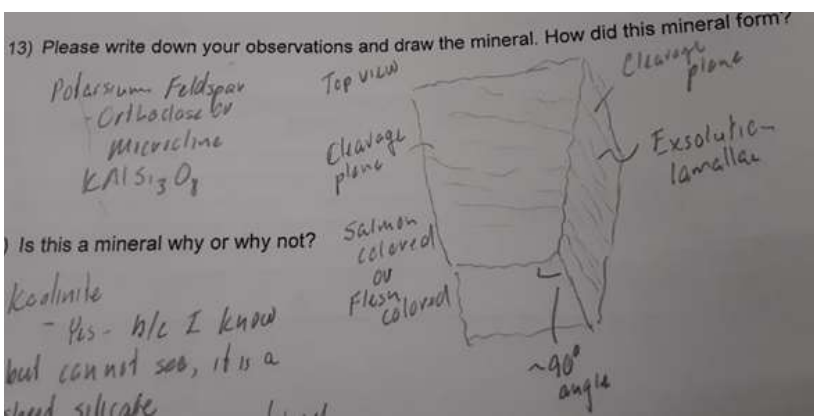

Figure C. 20: These images are from Interview 22, an Earth Science professor's interpretation of the potassium feldspar sample.

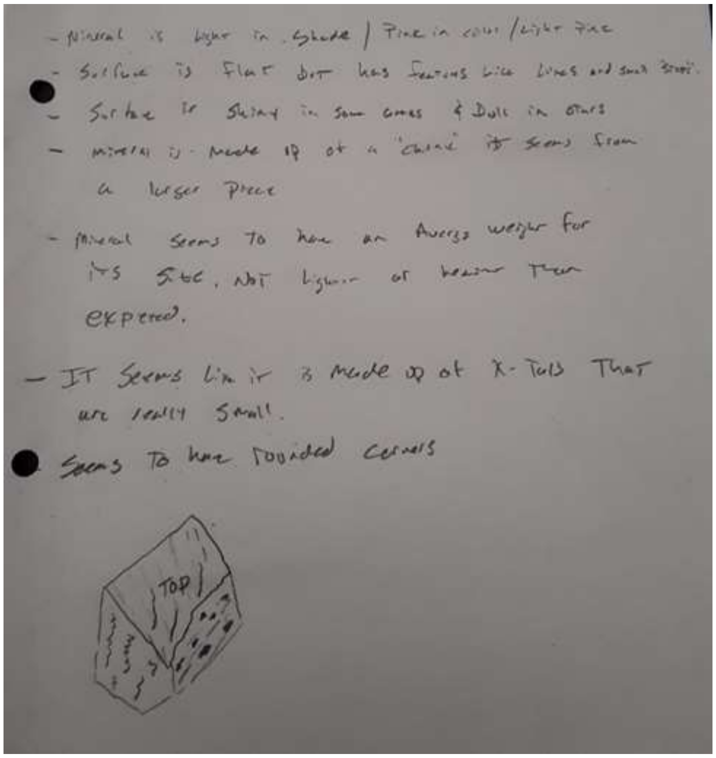

Figure C. 21: These images are from Interview 23, an Earth Science professor's interpretation of the potassium feldspar sample.

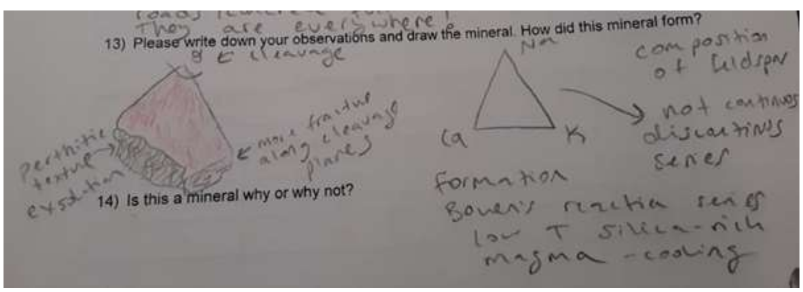

Figure C. 22: These images are from Interview 24, an Earth Science professor's interpretation of the potassium feldspar sample.