9-3-2013

Directing, Orienting and Orienteering: Supporting Students to Engage Consequentially

Nicholas Kvam

Nicholas Kvam
Candidate

Department of Teacher Education-Secondary Education
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Vanessa Svihla, Chairperson

Kersti Tyson

Justin Boyle

DIRECTING, ORIENTING AND ORIENTEERING: SUPPROTING STUDENTS TO ENGAGE CONSEQUENTIALLY

by

NICHOLAS DAVID KVAM

B.A., CHEMISTRY EDUCATION
CONCORDIA COLLEGE - MOORHEAD, MN
2009

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Arts
Secondary Education

The University of New Mexico
Albuquerque, New Mexico

July 2013

Dedication

In memory of my grandparents, Ernest and Ruth Kleinke and Spencer Kvam.

For my parents.

Acknowledgments

I would like to acknowledge the support of the many people who supported me through the completion of my Master's Thesis. I would like to thank my supervisor Vanessa Svihla and my committee members Kersti Tyson and Justin Boyle. Vanessa, thank you for the wonderful opportunity of being your research assistant and introducing me to this research. I appreciate your guidance, feedback, support and expertise through this process and for helping me find this unique path to take. You taught me to love research and sparked an interest that I will carry throughout my life. Justin and Kersti, thank you for the insight and support that you have provided. You both helped me do better work and gave me direction on my journey.

I would like to acknowledge the UNM ARTS Lab, David Beining and Jeff Bowles for their time and work. Thanks to Sushilla Knottenbelt and the other UNM Chemistry faculty for giving me access to their classes and to the TAs and students of the chemistry classes that I worked with. I would also like to thank Vanessa Svihla and Matt Dahlgren for giving me access to their classes and to the students in the teacher preparation courses that I worked with. Thanks to the members of IDDEA Lab for their support and feedback.

Special thanks to my wife and parents for their support and love. Dani, you lead me to this wonderful opportunity and gave me the support I needed to start this journey. You showed me that it could be done and I am so happy to share this path with you. I could not have done this without you and am excited to share what the future holds for us together. Mom and dad, you have always supported me in everything I have done. You instilled in me the love of reading and learning. Thank you for believing in me and for helping me accomplish my

dreams. I would also like to thank Tim and Nancy and my siblings, Ellie, Molly, and Isak for their love and support.

DIRECTING, ORIENTING AND ORIENTEERING:
SUPPRORTING STUDENTS TO ENGAGE CONSEQUENTIALLY

by

Nicholas D. Kvam, M.A.
B.A., Chemistry Education, Concordia College, 2009
M.A., Secondary Education, University of New Mexico, 2013

It is often difficult for teachers to support students to engage at a consequential level. The purpose of this study is to explore how learners orient themselves in learning environments and how this can support consequential engagement. I report on analyses that focus specifically on orienteering and orienting framing of learners in new environments, and contrast this with a traditional classroom in which teacher directing dominated. This study includes four cases. The first case involves a teacher using a starter at the beginning of class to review a science concept. The second case involves students using manipulatives as a way to learn about compounds and molecular elements (n=4). The third case also uses manipulatives, but in this case the students learn how to balance chemical equations (n=4). Participants from the second and third cases include students from a university chemistry course that has been designed for students “at-risk” of failing. The fourth case involves a teacher using immersive, interactive projection technology to teach arithmetic and geometric sequences (n= 9). Participants include students from a math pre-service teacher education course at the university level. Interaction analysis of video records was conducted using the software program *Comic Life 2*. In this study I explore:

- What frames of instructional and learning sequences support students to engage procedurally, conceptually, and consequentially? How might the

metaphor of orienteering, orienting, and directing make these frames clear?

- How might immersive, interactive technology disrupt a directing frame?

This analysis revealed multiple frames of instructional and learning sequences, including directing, orienting and orienteering. Directing is teacher-led and has very little room for student input. Orienting is more student-led, where the teacher guides the students in their understanding. Orienteering is student-led, where the students work together to create their own understanding. As a comparison, videos from a traditional middle school science classroom demonstrate teacher directing.

Based on analysis, I infer that orienteering invites generative activity and negotiating, but might not on its own result in learning. When followed up with orienting, however, the resultant engagement observed was conceptual. In contrast, directing tended to invite only procedural engagement. However, despite the use of directing in the immersive, interactive projection case, consequential engagement was observed; immersive, interactive projection provided a *disruption* – meaning it disrupted patterns of habituated practices--that supported students to engage in a consequential manner.

This study has implications for both instruction and curriculum design. If teachers want to see at least conceptual engagement, they should support students to first orienteer themselves and then later orient them. This study also has implications for further research. We don't know why the immersive, interactive projection provided this disruption and further research is needed. Finally, the study has methodological implications for using *Comic Life 2* for doing interaction analysis.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Rudolph (2005) argues that schools have been long criticized for not reflecting the professional practices of STEM scientists. Despite multiple reforms to address this issue, these professional practices are still not being developed in the classroom. A recent attempt to improve STEM practices is the American Recovery and Reinvestment Act, signed into law on February 17, 2009. This legislation aimed to create jobs, stimulate the economy, and invest in critical sectors, including education. A program called “Race to the Top” was developed as part of this law to invest in education: the second priority of this program was to create “competitive preference priority – emphasis on science, technology, engineering, and mathematics (STEM)” (U.S. Department of Education, 2009, p. 4). There were competitive grants offered to states and also to individual school districts that create a plan to offer rigorous STEM courses, work with STEM-capable community partners, and prepare more students to pursue advanced studies and careers in STEM. Diane Ravitch (2010) has been critical of this reform because there will be less time for subjects like science.

The National Research Council (NRC) (2012) claims that STEM is the solution to many of our current and future challenges as a society, but the number of workers with a strong STEM background does not meet the demand. The NRC formed a committee to create a framework for the recently released Next Generation Science Standards. The framework consists of three dimensions: scientific practices, crosscutting concepts, and disciplinary core ideas. New standards require students to develop these professional STEM practices (National Research Council, 2012; Common Core State Standards Initiative, 2010). STEM teachers are expected to align their teaching practices to these new standards and provide a rigorous curriculum to support their students in meeting the reform expectations. This will require teachers to develop different skills and learn innovative strategies to support students’ learning.

First and foremost, teachers must support students to engage in a consequential manner. This type of engagement is essential for the development of STEM practices. Consequential engagement provides students the opportunity for students to make connections across issues and develop the skills that will be essential in providing solutions to many of our current and future challenges as a society.

For students to develop these new skills, teachers must support students to engage with the material in multiple ways. There have been past reform efforts, but instruction still remains fairly traditional. Scaffolded problem-based learning is a common solution to address this issue. STEM practices are not supported when an activity is highly scaffolded. However, when scaffolding is too low, learning is not supported (Kirschner, Sweller & Clark, 2006).

One strategy to support teacher-student engagement, which is proposed in this study, is the use of interactive, immersive technology. Such environments have the potential to prepare teachers to engage students in consequential ways. The technologies vary in their capabilities and serve different purposes, but they all share common characteristics that have the potential to support students in the development of STEM practices through teacher support. The characteristics of these technologies include: supporting multiple forms of engagement, an interactive, immersive display, having a sensory presence, creating a narrative that invites participation, and allowing students to take on roles; these are discussed below.

Chapter two reviews literature on why a lack of consequential engagement has consequences for what students can do; how levels of scaffolding relate to forms of engagement; and how immersive, interactive media has unique affordances for supporting learning. This reveals gaps in understanding. Chapter three describes the methods used in this study. Chapter four presents the results of my video and interaction analysis, and finally, chapter five discusses findings and presents conclusions.

Chapter 2: Literature Review

A lack of consequential engagement has consequences for what students can(not) do

When students engage with the curriculum at a deeper level they develop the STEM practices that are so highly valued in the new science standards and educational programs. Gresalfi & Barab (2011) created a framework that consists of four different forms of engagement. They explained that there are a variety of ways to define engagement and many different conceptualizations about the source of different forms of engagement. They argue that, "engagement is neither a property of the individual nor of the environment but, rather, the result of an interaction between the two" (p. 302). This stance helped the authors identify and define forms of engagement, and conceptualize the sources of the engagement.

The forms of engagement the authors developed are procedural, conceptual, consequential, and critical. Gresalfi & Barab (2011) differentiated these forms of engagement as:

Table 2.1. Forms of Engagement

Engagement	*Defined as*
Procedural	"involves using procedures accurately, but not necessarily with an understanding of why one is performing such procedures." (p. 302).
Conceptual	"involves more than plugging numbers into an equation, but additionally involves understanding why an equation works the way it does." (p. 302).

Consequential	"involves recognizing the usefulness and impact of disciplinary content; being able to connect particular solutions to particular outcomes." (p. 302).
Critical	"involves questioning the appropriateness of using particular disciplinary procedures for attaining desired ends." (p. 302)

Procedural and conceptual forms of engagement explain how students think about content. Consequential and critical engagement explain the decision-making process that students use when problem solving and how they evaluate the validity of the method they are implementing. After identifying, defining, and conceptualizing these forms of engagement, the authors put it into context.

Gresalfi & Barab (2011) studied how students embody these different forms of engagement as they participated in a multiplayer online video game. The mathematical concepts that were being taught in this environment are mean, median, and mode. The sixth-grade math standard required students to compare these measures with a dataset. They had to develop the skills to calculate each measure and determine which was most fitting to use, given the data they were presented. The students had to decide which mayoral candidate made the best decisions for children in town. One mayoral candidate believed that traditional methods are best for the town and the other believed that innovative methods are better. Both candidates claimed to have statistical data to support their politics and the students had to decide which one made the best argument. Through this process, students embodied all four forms of engagement. First they engaged in a procedural manner by calculating the mean, median and mode. As they progressed through the game, the students engaged in a conceptual manner. This means that they could explain what they mean, median and mode meant. The students engaged consequentially by understanding the implications of these measures. For example, a student expressed that although it is important to stop quickly, it is also important to be able to predict when a bike will stop. Finally, the students engaged in a critical manner when they questioned the validity of each mayoral candidate's argument by critically assessing the mean, median and mode.

When students were able to engage with content across these four forms, it allowed them to develop a deeper, more consequential level of understanding, which is highlighted in the STEM practices. Multiple forms of engagement and allowing for students to engage consequentially are changing how students experience school (Gresalfi & Barab, 2011). Consequential engagement is essential for the development of STEM practices. Scaffolds can be used to support students to engage in different ways.

Levels of scaffolding relate to form of engagement

Vygotsky (1978) developed the notion of Zone of Proximal Development (ZPD),defined as, "the distance between the actual developmental level as determined by independent problem solving and level of potential development as determined though problem solving under adult guidance or in collaboration with more capable peer" (p. 86). An applied notion of ZPD is *scaffolding*. Wood, Bruner, and Ross (1976) first defined scaffolding as a "process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (p. 90). Studies have shown that scaffolding can support learning STEM content (Hmelo-Silver, Duncan & Chin, 2007; Kyza, 2009; Quintana et al., 2004; Sandoval & Reiser, 2004)).

Some research has also found support for using scaffolding to learn STEM practices. These practices are mostly supported in long-term activities such as project-based learning (Barron et al., 1998; Singer, Marx, Krajcik & Chambers, 2000). Puntambekar and Kolodner (2005) looked at the use of scaffolds in a science classroom that used *Learning-by-Design* units. The first tool they used to help scaffold design was a design diary. It had prompts to help the students carry out each design step and write down important information. The authors used a seven-part coding scheme to analyze the diaries and they found that they needed more scaffolding than just the design diary. The design diary did not provide some scaffolding that the students needed and the students were given too much independence. It was concluded there was a need for more specific prompts and a need for distributed scaffolding in the classroom.

Puntambekar and Kolodner's second study had three major changes (2005). First, they redesigned the design diaries to connect different phases to each other. Next, they added scaffolding to the diaries to support students to consider structure, function and behavior of the devices they were designing and modeling. Finally, new activities were developed that provided more student-student and teacher-student interactions. Again, the seven-part scheming code was used to analyze the diaries and the authors concluded that the distributed-scaffolding implementation that, "students showed a deeper understanding of the usefulness and applicability of the science that they were learning" (p. 37-38). The authors believed this is supported by the fact that the diaries were designed to encourage the students to reason about their design decisions and make predictions and figuring out if those predictions were correct.

Puntambekar and Kolodner (2005) also expressed that there are limitations to how much scaffolding one tool can offer and the multiple types of tools available to scaffold for the range of needs that learners have. It is clear that scaffolding is essential for supporting learners in the development of STEM practices. Using immersive, interactive technology might also support students to engage with the curriculum and develop STEM practices, in part because of characteristics such as sensory presence, narrative, and role-play.

Immersive, interactive media has unique affordances for supporting learning

Immersive, interactive displays take many different forms including panoramic displays (e.g. digital domes or large flat screens), panoramic field of regard (e.g., head-mounted displays) and stereographic images (e.g., shutter glasses or polarizing filter glasses) (Jacobson, 2012). These settings are considered virtual environments, which are defined as a three-dimensional world for immersive user interaction. They come in a variety of formats including computer games, video games, online virtual environments, and online digital learning platforms (Dickey 2006; Dede 2009; Linn & Slotta 2000). These technologies support learning, providing opportunities that are not possible outside of these technologies.

Immersive environments provide many benefits. Immersive, interactive displays support factual recall and conceptual learning of architecture (Jacobson, 2010) and chemical reactions (Limniou, Roberts, & Papadopoulos, 2008). Interactivity may be an important key for creating narrative and sensory presence, and in turn support learning (Dondlinger, 2007). Narrative presence is when the learners feel like they are part of a story and can help shape it; sensory presence is when the learners feel like they are part of a virtual world by stimulating their senses (Jacobson, 2012). Verifying that immersive, interactive technologies support learning (and even increase learning in some cases) is crucial in using them to support multiple forms of engagement. The displays can also provide many opportunities that students would not be exposed to without these technologies.

The use of immersive, interactive technology can provide many opportunities to support learning in ways that are not easily attainable in “real-life” situations. The displays allow the user to study very small- or large-scale perspective. For instance, they could be programmed to look at chemical reactions at the atomic level or to observe how global climate change is affecting the entire planet earth. They also allow students to go places that are not easily accessible—such as travel into outer space to study the galaxy or dive into the oceans to study marine life. These technologies provide opportunities to control time, allowing students to travel back in time to visit an ancient city or follow the events of a previous war, or to speed up or slow down time, allowing students to watch phenomena that occur either so quickly or so slowly that they otherwise would not be easily observed. The ability of these technologies to be manipulated is what provides their utility (Dondlinger, 2007).

Immersive, interactive environments also provide students a sense of *presence*—a feeling that they are participating in virtual environments. Sensory presence enhances engagement, which in turn leads to greater learning (Fraser et al., 2012). Virtual environments allow learners to feel more present (Kafai, 2006). Even online, interactive environments can evoke a sense of presence (Lessiter, Freeman, Keoggh, & Davidoff, 2001). Kafai (2006) also emphasizes the importance of level of presence that children display when they are playing video games. This type of presence is not seen when just watching television programs or a movie. Video games are clearly affording something that is not provided by non-interactive forms of media. Lassiter and colleagues (2001) say that the sense of "being there" is what creates presence. The user's presence is determined by media characteristics and user characteristics. Media characteristics are either the media form—that is, the physical properties of the display-- or the media content—that is, the theme or story created. User characteristics are user's abilities and personality traits. These combine to create the overall sense of presence a user gets when operating in an interactive display. Immersive, interactive displays come in multiple formats, they support learning by providing opportunities that are difficult to attain in "real-life" situations and by creating sensory presence. These attributes of immersive, interactive displays create an opportunity for students to engage in a variety of ways.

Additional attributes that support these different forms of engagement include providing a narrative and allowing the students to take on roles. Dickey (2006) used video games and computer games to develop a framework for a narrative. She claims that these games provide a motivating context and a cognitive framework to create a narrative that can be conveyed throughout the game. The implementation of roles is also a fundamental element in developing a narrative context.

Narrative in video games provides a motivating context for problem solving (Dickey, 2006; Gresalfi & Barab, 2011). Dickey argues that, "Narrative is typically used to establish the setting and initial motivation, but often it is not the main focus of the game" (p. 249). Players collect items, interact with other characters, access information from multiple sources, and develop skills throughout the game to help create the narrative. There are two primary techniques that are used to motivate. The first is plot hooks. Plot hooks create unanswered questions that keep the player interested in the game. The player usually must make a decision or respond to something that has happened. These plot hooks must be authentic and should put the player in the action without much explanation. There should be multiple plot hooks that support each other and motivate the player to move from one question to the next. The other technique used for motivation is in emotional proximity. Emotional proximity is how the player identifies with the character in the game. Again, authenticity is important and to support this, the character in the game must have characteristics that the player can identify with. The character should show emotions and have strengths and weaknesses.

Narrative in video games also provides a cognitive framework (Dickey, 2006). The narrative storyline in the game allows players to "identify and construct casual patterns that integrate what is known (backstory, environment, rules, etc.) with that which is conjectural yet plausible within the context of the story" (p. 252). The plausibility is created with a backstory that creates boundaries. Physical, temporal, environmental, emotional, and ethical dimensions are created to support the backstory. Based upon the boundaries that have been created, the player makes plausible conjectures about solving problems and answering questions. This provides a cognitive framework for the narrative.

Dickey outlines how to integrate game design narrative for instruction in the classroom. First, an initial challenge must be presented. This should be a problem that will drive the story and goals for learning. A backstory should be created and cut scenes should be used to provide context and to support the narrative throughout the game. It is important to identify potential problems that the students will face within the lesson and provide resources that can assist them. It is also useful to set up minor challenges or puzzles to help develop skills that the student will need to complete the central challenge. Creating roles within the game -- along with physical, temporal, environmental, emotional, and ethical dimensions -- supports the narrative and helps the experience feel authentic. Dede (2009) calls this experience situated learning, and he argues that authentic contexts, activities, and assessments should be created to support narrative.

Some narratives allow students to take on roles and identities of scientists (Dunleavy, Dede, & Mitchell, 2009). Games can often serve as a mediator between virtual and real identities, engaging students previously uninterested and allowing them to take on roles they would have otherwise not assumed. Roles that are created should be authentic. These are not the typical roles (e.g. recorder, presenter, leader, etc.) that one is assigned when working on a group project. Roles that are created in these technologies embody an actual profession or character. Role-playing as scientists has been shown to help learners understand that the objectives of science are not generating facts so much as developing and testing explanations (Solomon, Duveen, Scot, & McCarthy, 1992). Role-play, particularly when rooted in narrative that creates a role in which action can be taken by the user, has been shown to support learning (Barab et al., 2010).

Creating a narrative is a valuable approach to develop within the curriculum that is being implemented. It provides a motivating context and a cognitive framework for the narrative and allows for this to be used with immersive, interactive technologies. Role-playing also creates opportunities for learners to better understand the actual practices of a profession and enable them to authentically participate in the narrative. When roles are created and a narrative is provided, it allows students to engage in multiple ways and supports the development of STEM practices.

Gaps in understanding

To development of STEM practices, students have to engage in a consequential manner. There are many features that support this development that are unclear. For instance, what does engagement look like when learning it is not yet fully developed? It is also unclear how to scaffold engagement when learning is in this state. We especially don't know how to scaffold the development of practices, particularly for shorter-term problem (as opposed to project) based learning. While research has shown that students can learn STEM content with immersive, interactive projection, less is known about how such technology might be used to scaffold learning of STEM practices.

Research Questions

- What frames of instructional and learning sequences support students to engage procedurally, conceptually, and consequentially? How might the metaphor of orienteering, orienting, and directing make these frames clear?

- How might immersive, interactive technology disrupt a directing frame?

Chapter 3: Methods

I present four cases that were analyzed using interaction analysis and cross-case comparison. I compared these cases to consider framing and the forms of engagement.

Settings and Participants

The first case took place in a traditional middle school science classroom and depicts a starter question activity. The second and third cases both took place in a basic chemistry course at the university level and were covering the topics of mixtures and balancing equations. The fourth case was a set in an elementary mathematics pre-service teacher education course during an activity focused on the topic of sequences. These cases had various levels of scaffolding and each had a different role of technology or other instructional material as supports (Table 3.1).

Table 3.1. Cases included in the study

Case	*Level of Scaffolding*	*Role of technology or other instructional materials*
Case 1: Traditional Science Instruction	High	For the segment selected, only a whiteboard is used, but in the original study (Svihla & Linn, 2011), the Web-based Inquiry Science Environment was used.
Case 2: Paperclips 1	Moderate	Paperclips used as manipulatives.
Case 3: Paperclips 2	Low	Paperclips used as manipulatives.

Case 4: DomeStroids	High/Moderate	Immersive, interactive projection is used to display simulations

Case 1: Traditional Science Instruction

The participants in this study include 6th grade students (N=35) and a teacher in a diverse middle school classroom. The data for this case were collected as part of another study (Svihla & Linn, 2011). Video data were collected during several class periods. Ten videos were reviewed to deliberately select a segment showing traditional science instruction. For this study, only the first minutes of one class are used. Data were first listened to then transcribed.

Cases 2 and 3: Paperclips

Two cases were drawn from a larger sample of students (n=23) and instructors (n=4) that are part of a basic chemistry course taught at the university level. This course is designed for students who are at-risk of failing the introductory chemistry course. The study gained IRB approval and students and instructors included in the study gave consent. Class groups were composed of two to six students who were assigned by the instructors. The two cases show the same group engaged in two different activities.

The two different activities, both using manipulatives, were video recorded. The first activity had the students use paperclips to represent a compound and a molecular element (See Appendix). They then had to use these representations to create a mixture and explain why it is considered a mixture. The second activity had the students use paperclips to balance chemical equations. They had to use the paperclips to first create the reactants of the reaction, and then use those to create the products. They also had to draw representations of their reactants and products on a worksheet and record the balanced equation. Field notes were also collected.

There are a total of eleven video files ranging from four minutes to forty-two minutes in length. There are four pages of field notes. Video data were first listened to then transcribed. The two cases that were selected to be part of this study were based on two criteria. First, the video records had to be audible. Two of the recordings were almost completely inaudible and very little data could be interpreted. Second, the data exemplified one or more of the following frames of instructional and learning sequences: directing, orienting, or orienteering.

Case 4: DomeStroids

The participants in this study included students (n=9) and an instructor that were part of a math pre-service teacher education course at the university level. The study gained IRB approval and the students and instructor included in the study gave consent. Video and field notes were collected as data. Data were collected over three fifty-minute class periods. One period of video data were collected during an activity in am immersive, interactive projection dome activity (See Appendix). This dome is similar to a small planetarium and has a 15-foot diameter. It provides an immersive field of view that allows 12-15 students participate together. Field notes were taken during the period prior and the period after the dome activity. Video data were first listened to and then transcribed.

Video and interaction analysis

All video data were analyzed using interaction analysis. Jordan and Henderson (1995) define interaction analysis as, "an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment" (p. 39). The authors acknowledge that no method is without theoretical assumptions and that interaction analysis holds three assumptions. These assumptions are: (1) "knowledge and action are fundamentally social in origin, organization, and use, and are situated in particular social and material ecologies", (2) "verifiable observation provides the best foundation for analytic knowledge of the world", and (3) "the domain of questions of interest … revolves around the achievement of social order (and ordering) in everyday settings" (p. 41). Interaction analysis has become increasingly common in part because of the vast amount of work that is being done with electronic recording. Video data are also the only format that provides the amount of data required for this type of analysis. The authors explain that video data are useful because they reconstruct the event so well; video is a permanent record that can be viewed multiple times and is very helpful with the complexity of interaction data. Interaction analysis was very useful for the data from this thesis.

More general video analysis procedures were also used to analyze data (Barron & Engle, 2007; Derry et al., 2010; Hall, 2007; Hall, 200). Video recordings were watched and the transcript was reviewed with those of varying levels of familiarity with the activity. This allowed me to go from a large-scale interpretation and narrow down to focus on specific case studies (Radin & Becker, 1992; Yin, 2003).

The software application *Comic Life* was used to create annotated scenes from the video data. Screenshots were taken from the video and embedded into *Comic Life* as still images. These screenshots were taken at the point in the scene that best depicted the action that was occurring. Transcript from the scene was added in as conversation bubbles. Time lapses and actions were recorded in captions in the bottom of the scene. Arrows were also added to the scenes to indicate what the conversation was referencing. A key was created to guide the reader on how to interpret the annotated scenes.

Initially, I used Gresalfi & Barab's (2011) framework of forms of engagement described in the literature review (procedural, conceptual, consequential and critical). I coded several transcripts but had trouble using this framework to categorize what was occurring in my data. While there were instances that could be categorized as procedural, conceptual and consequential engagement, there were interesting cases of nascent learning that did not fit the framework. In my results, I present the framework that I developed to define these instructional and learning sequences that were not captured by Gresalfi & Barab's (2011) framework.

Chapter 4: Results

I present four separate cases that portray instructional and learning sequences. While Gresalfi & Barab's (2011) forms of engagement were present, I also developed a new framework to capture the nascent learning visible in instructional and learning sequences. I will first present this framework that was developed from my analysis and then I will present the cases out of which the framework was developed. My framework consists of three frames -- directing, orienting and orienteering. The frames are defined in Table 4.1 and exemplified in cases.

Table 4.1. Definitions of frames.

Frame	*Definition*
Directing	High level of teacher directing where students have little control over their learning in an instructional and learning sequence.
Orienting	Teacher or instructional materials guides the students through an instructional and learning sequence. Students have some control or their ideas are taken up.
Orienteering	No teacher interaction where students completely control an instructional and learning sequence. Instructional materials are ignored, unclear, or not prescriptive.

These frames are supported in the cases that I will present. Instructional and learning sequences can lead to a variety of forms of engagement -- procedural, conceptual, or consequential. My aim is to connect the framing of the instructional and learning sequence to the later form of engagement. During an instructional and learning sequence multiple frames can be present; for example a teacher could start by directing and then move to orienting. Likewise, during an instructional and learning sequence, multiple forms of engagement can also be present; for example students could first engage in a procedural manner and then engage conceptually.

Case 1: Directing Traditional STEM Instruction

The first frame I see surface from this data is *directing*. I define directing as a high level of teacher directing where students have little control over their learning in an instructional and learning sequence. This is a very common activity in the traditional classroom setting. The teacher directs the students to an answer and there is very little discussion or understanding as to why the answer is correct. In this study, directing is exhibited in a starter question activity.

The goal of the starter question activity is to frame what the students will be learning about in their lesson for the day. The teacher has the question written on the left side of whiteboard (Figure 4.1). The teacher asks the students to write the question down in their notebooks. There is a brief answer and response to the question and then the teacher moves on to the next activity.

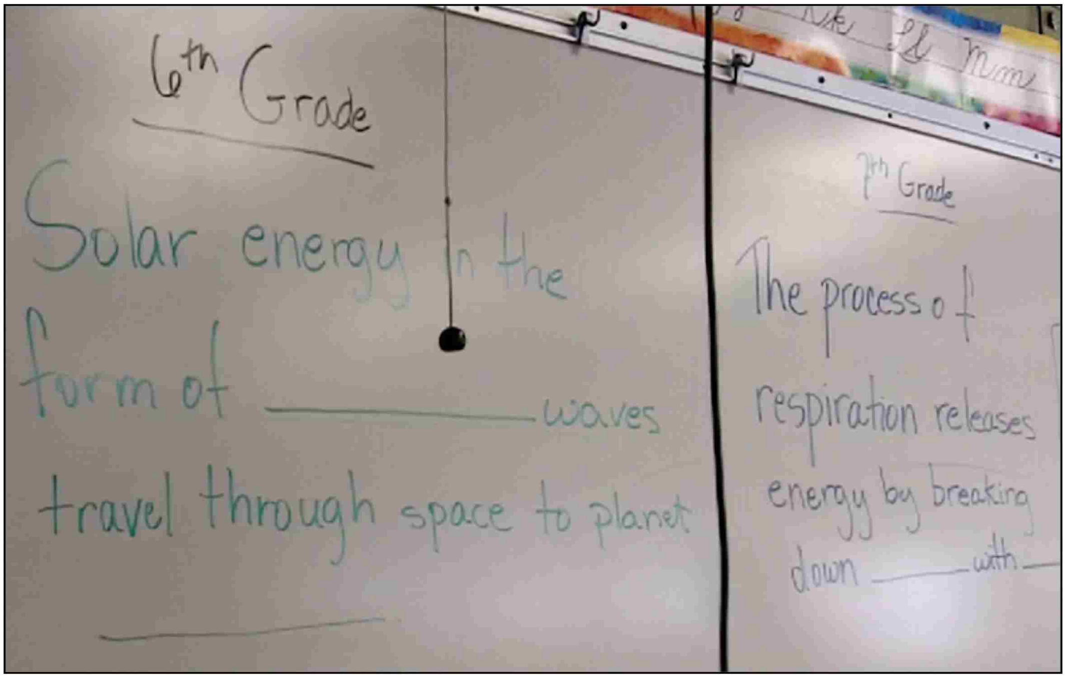

Figure 4.1 The question that the students had to answer.

The following transcript is the conversation that took place during the starter question activity. The transcript includes the teacher—Mrs. Olson-- and a student named David (both pseudonyms).

Mrs. O: Please write down your starter. ((47s))
Mrs. O: ‘Kay, starter is on the board, write it down please. ((63s))
Mrs. O: ‘Kay guys, open up. Who has an answer for the starter?
David: Me. Earth.
Mrs. O: Earth is right, or Mars or whatever, but what’s the first one? Solar energy comes here in the form of what? ((8s))
David: Umm, electromagnetic.
Mrs. O: Electromagnetic waves. Electromagnetic waves.

The question that is written on the board has two words missing, and the students have to fill in blanks to complete the question. There are no follow-up questions nor do the students have to connect this information to anything else. This type of question does not force the students to understand why the answer they provide is valid or how it would relate to what they have been learning.

In line 3, the Mrs. Olson asks the students to provide their answer. She does not give them to opportunity to discuss their ideas with another student. If this opportunity was provided, the students could have a discussion as to why their answer may be correct or incorrect. They would also have the opportunity to support their answer by connecting it to something that they had previously learned.

In lines 4 through 8, the David answers with one word and Mrs. Olson only responds to tell him that he is correct. She does not ask him to support his answer nor does she ask any other students if that is the answer that they decided on. Students who did not arrive at the correct answer or even write an answer at all have no understanding as to why they are incorrect. The only information that they receive from this interaction is that their answer is incorrect and that the right answer is earth or some other planet.

This transcript presents a very familiar scene in a traditional classroom. The teacher is directing the students as she asks a basic question and the student gives a short response. The answer that was given was correct, so the teacher approves the answer and repeats it back to the class to make sure everyone heard the answer. The teacher then moves onto the next activity. Although the students were given time to formulate their own answer, they were not given the opportunity to discuss their ideas with others. This activity did not give the students the opportunity to understand the material beyond a very basic level. The students were not able to engage with the material at even a conceptual level or develop their own understanding. This is a clear example of procedural engagement, where the students are using the correct terms and ideas, but don't demonstrate understanding of why they are using them.

Case 2: Orienteering followed by Orienting with Paperclips

In this case, we will first see the orienteering frame followed by the orienting frame. I define orienteering as no teacher interaction where students completely control the instructional and learning sequence. Instructional materials are ignored, unclear, or not prescriptive. Orienteering occurs when students are working together and trying to make sense of what they understand. Some type of activity or lesson may have been developed for the students to accomplish. The teacher may have provided directions or guidelines, but aside from this the teacher is not present in the process. I define orienting as teacher or instructional materials that guide the students through an instructional and learning sequence. Students have some control or their ideas can be taken up. With orienting, the students have a much more prominent role than in directing. The teacher usually does not give the students the answer directly; instead the teacher will ask students additional questions to scaffold their understanding. It is also common for the teacher to ask the students to explain their answer or provide support as to why their answer is correct.

Orienteering and then orienting are exemplified in a paperclip activity, the goal of which is to use paperclips to create a molecular element and a compound. The students are supposed to explain why each molecule is either a compound or molecular element. Once they have built these two molecules with the paperclips, they are supposed to put them in a plastic bag to create a "mixture." Finally, they have to remove the paperclips from the bag and explain what they created is considered a mixture. During the activity, this group of students worked through the problem on their own and completed the activity. At the end, they were confused because the explanation seemed too basic and they are not sure that they were correct. The group asked the teacher to come over to check to see if they are correct.

I present this case as a sequence of annotated scenes. There is a key (Figure 4.2) that describes how to interpret annotated scenes. Depicted are the conversation and actions that occur while the students orienteer themselves (Figure 4.3 – Figure 415.) and this is followed by the teacher orienting the four students in their understanding (Figure 416. – Figure 4.26).

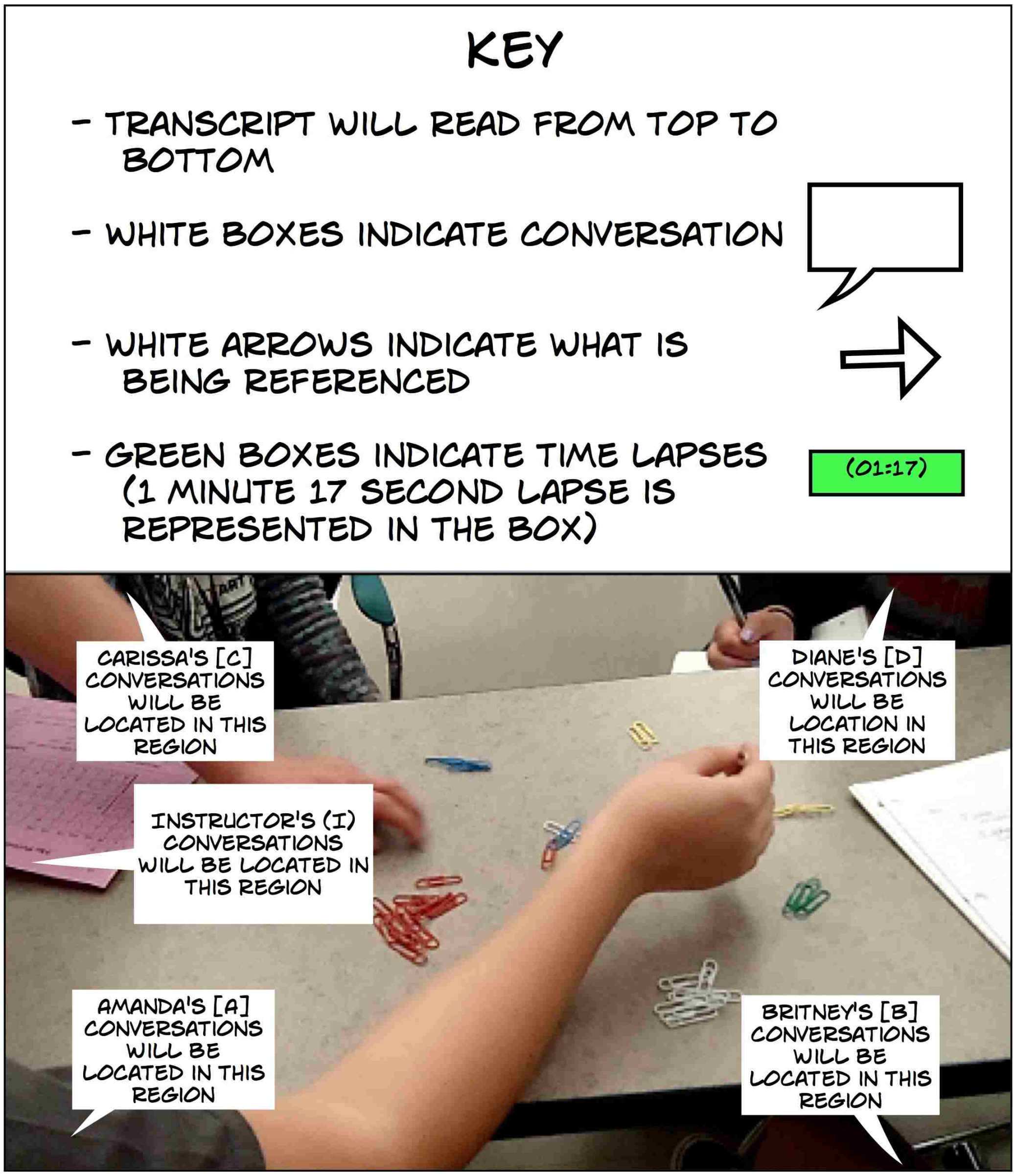

Figure 4.2 Key for understanding the annotated scenes.

Orienteering

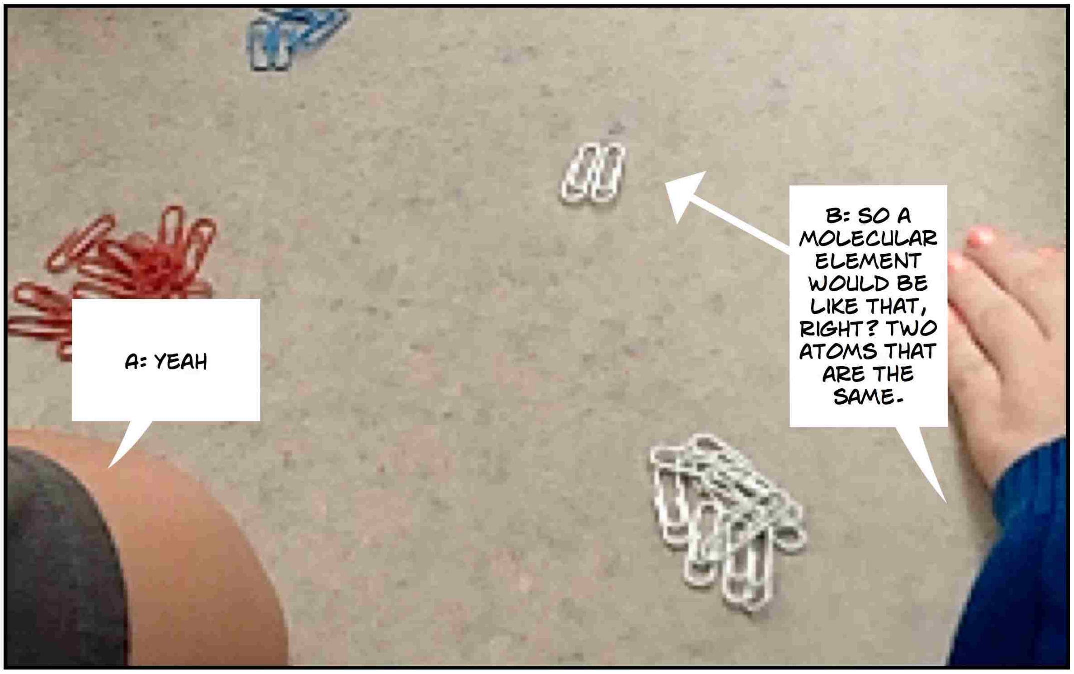

Figure 4.3 Annotated Scene 1

Figure 4.3 shows Britney creating a molecular element and asking Amanda if it is correct. Amanda confirms that it is correct. Britney's comment expresses that she understands this concept. In the next scene Britney explains that they need to create a compound (Figure 4.4).

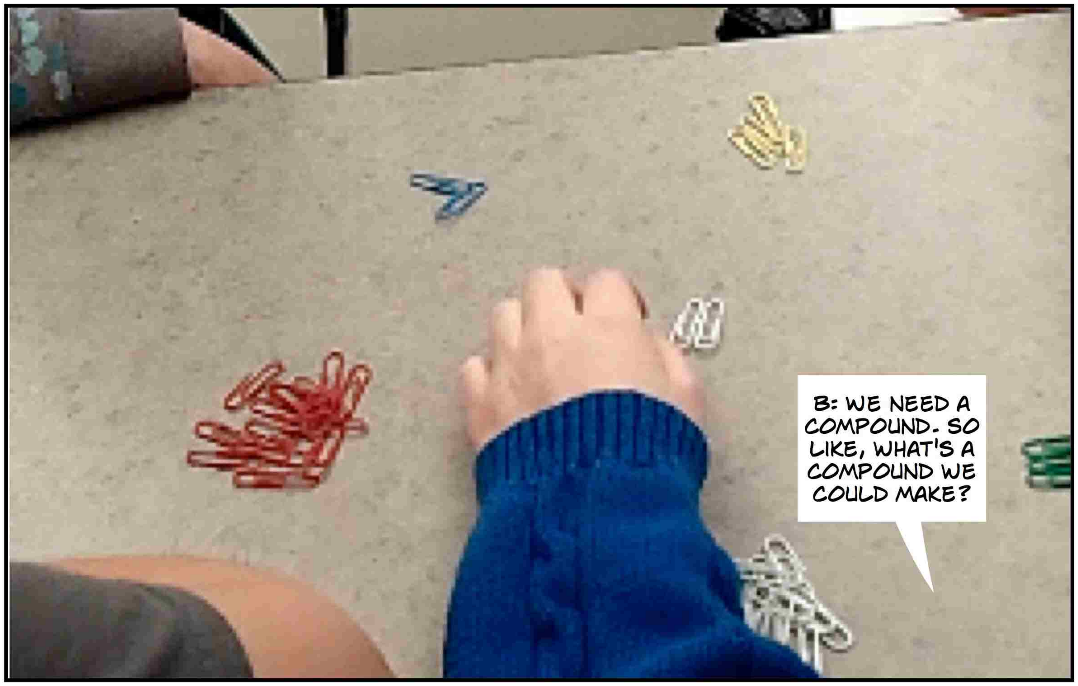

Figure 4.4 Annotated Scene 2

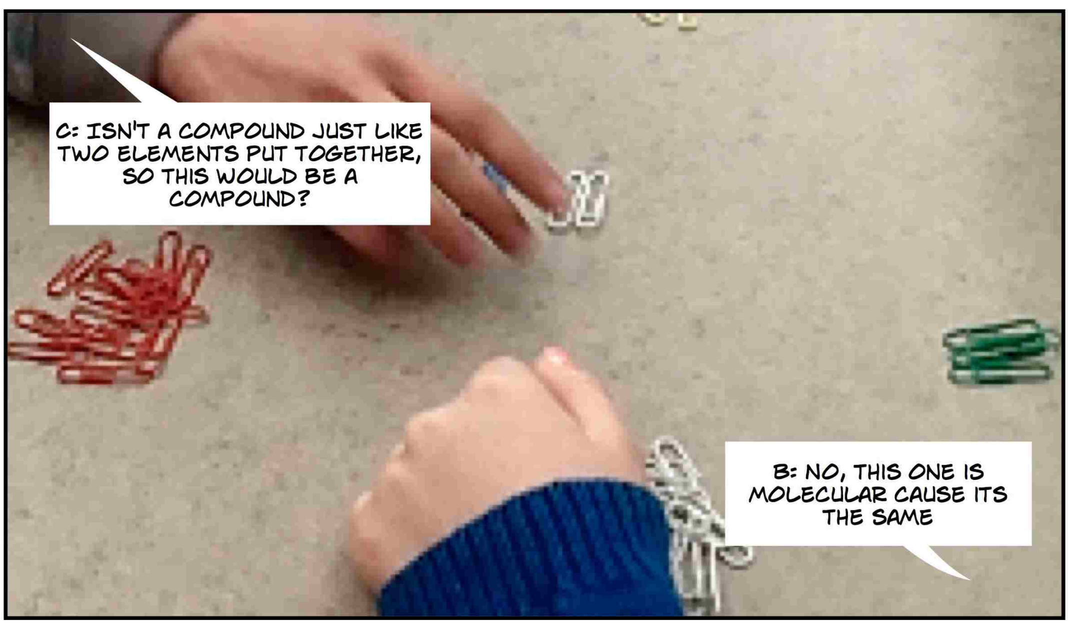

Figure 4.5 Annotated Scene 3

In Figure 4.4, Britney expresses that the group needs to create a compound with the paperclips. In Figure 4.5, Carissa suggests that the molecule created previously (Scene 1) would be a compound. Britney does not agree with this and explains that the molecule is a molecular element, because the two paperclips used were the same color. Here we see Britney and Carissa orienteering a path to understand the concept of a compound. In the next scene, Amanda asks if the compound is ionic or covalent.

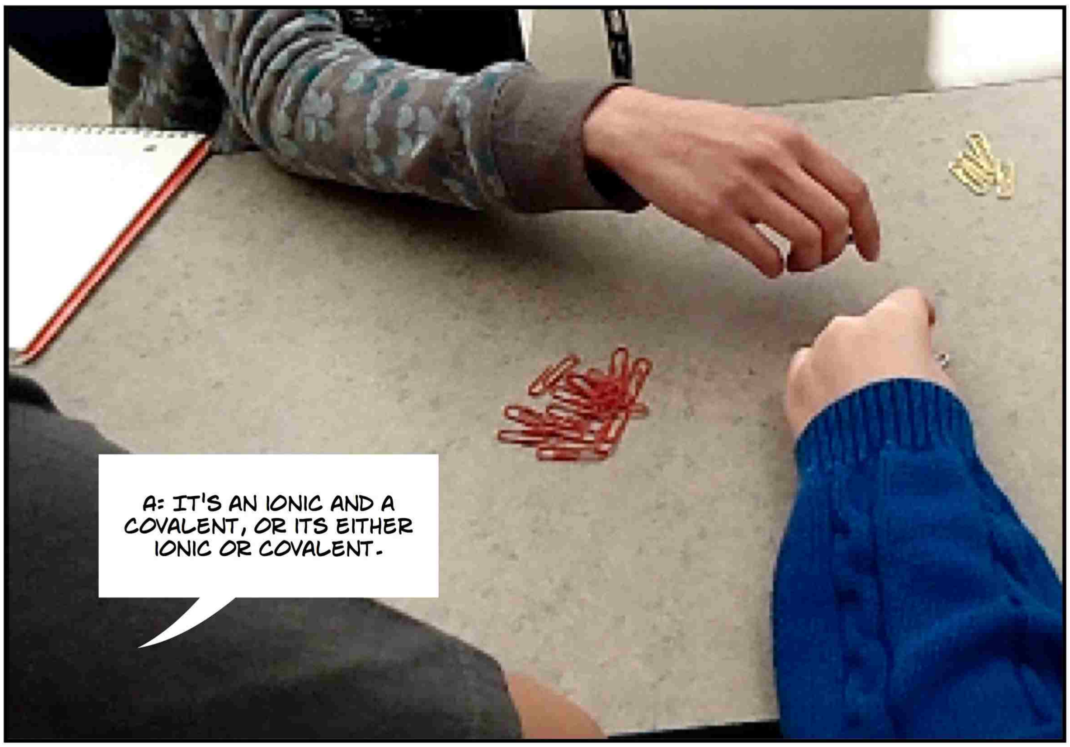

Figure 4.6 Annotated Scene 4

In Figure 4.6, Amanda asks if the compound is ionic or covalent. This is extraneous information that is not integral to solving the problem. Recruiting extraneous information is not uncommon when students orienteer themselves. In Figure 4.7, Britney does not respond to this question and moves on without addressing it.

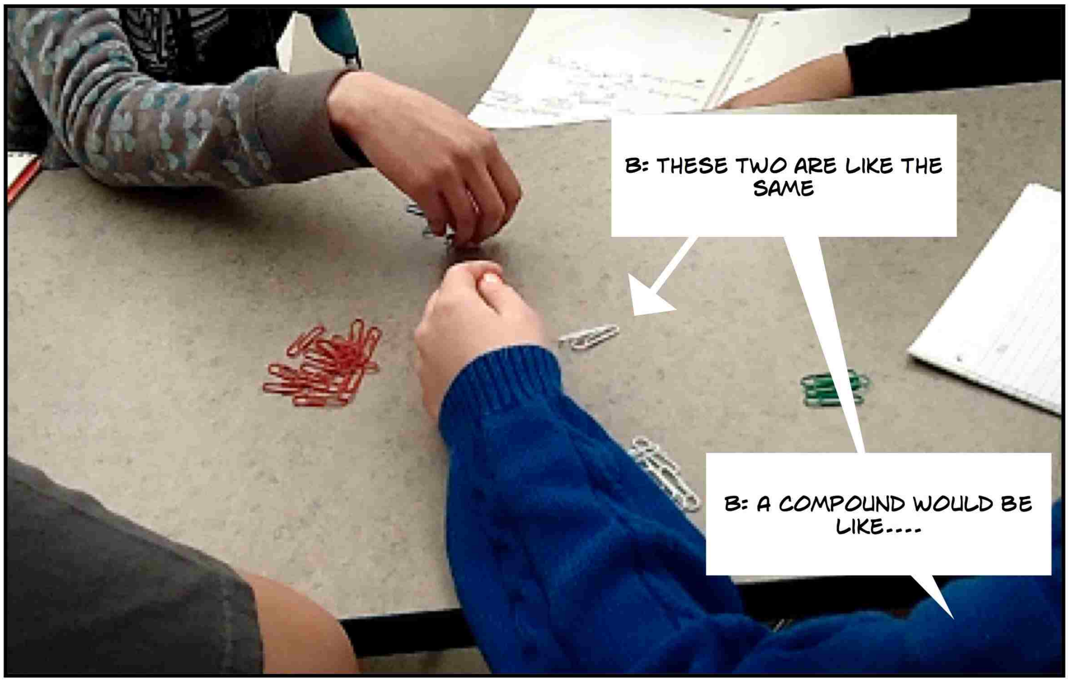

Figure 4.7 Annotated Scene 5

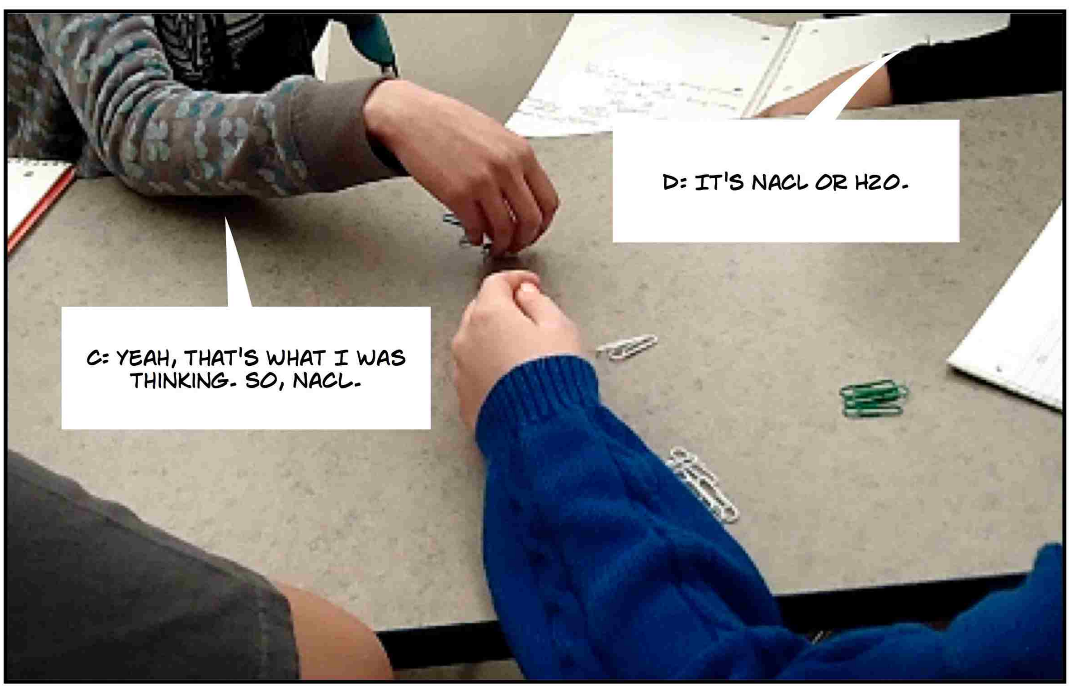

Figure 4.8 Annotated Scene 6

In Figure 4.7, Britney again explains that the molecule created first (scene 1) is a molecular element because the paperclips used are the same color. She does this to help frame her thinking about what a compound would be. She asks the group what a compound would be. In Figure 4.8, Diane suggests that a compound could be NaCl. Carissa agrees with this. Here, the group starts to orienteer an understanding around what a compound is. In Figure 4.9, Britney creates this compound using paperclips.

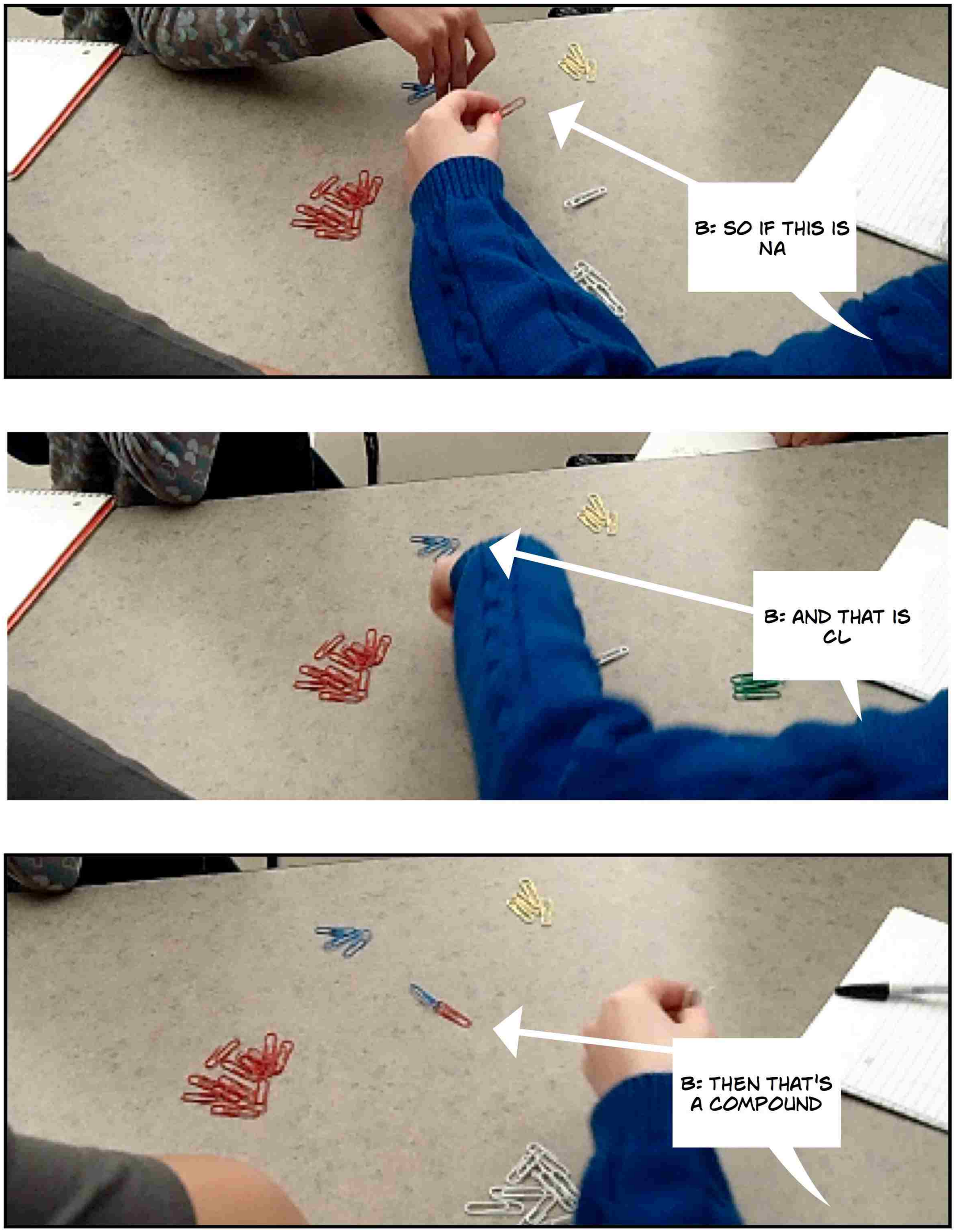

Figure 4.9 Annotated Scenes 7, 8 & 9

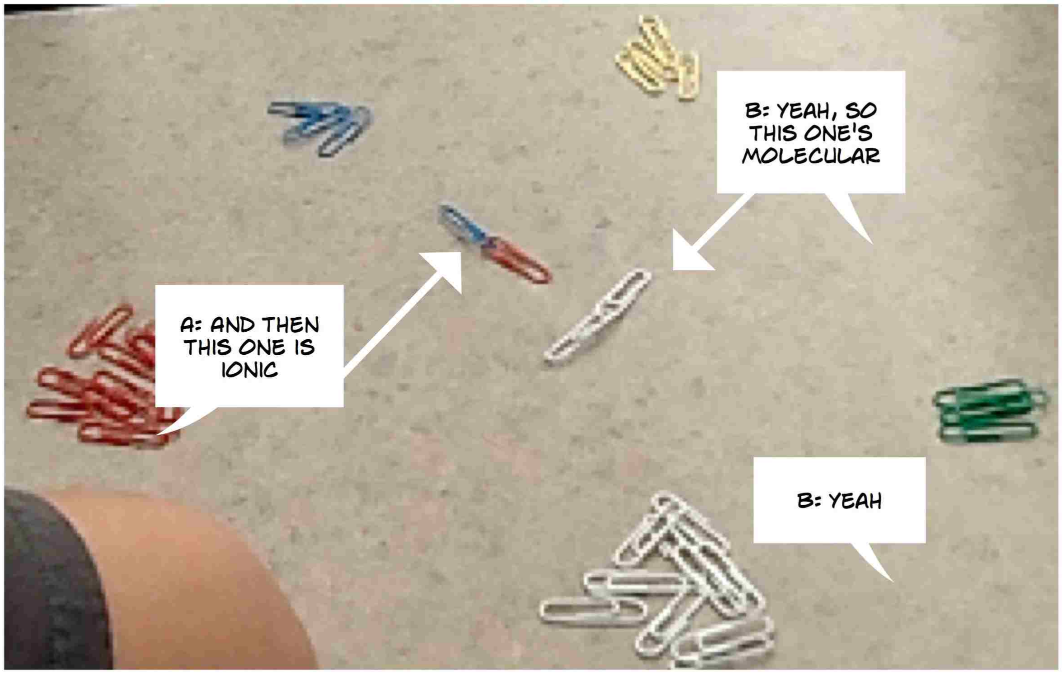

Figure 4.10 Annotated Scene 10

In Figure 4.9, Britney takes a red paper clip and a blue paper clip and links them together to create a compound. Britney has shown that she understands the concept when she expresses, “So if this is Na, and that is Cl, then that’s a compound.” Here Britney follows the procedure accurately and understands why it is correct. In Figure 4.10, Britney and Amanda confirm that the group has created both a molecular element and a compound. Together, the group has orienteered an understanding about the concept of what a compound is, what a molecular element is, and why. After confirming that both a compound and molecular element have been created, Amanda puts the paperclips in the bag to represent a mixture being created (Figure 4.11).

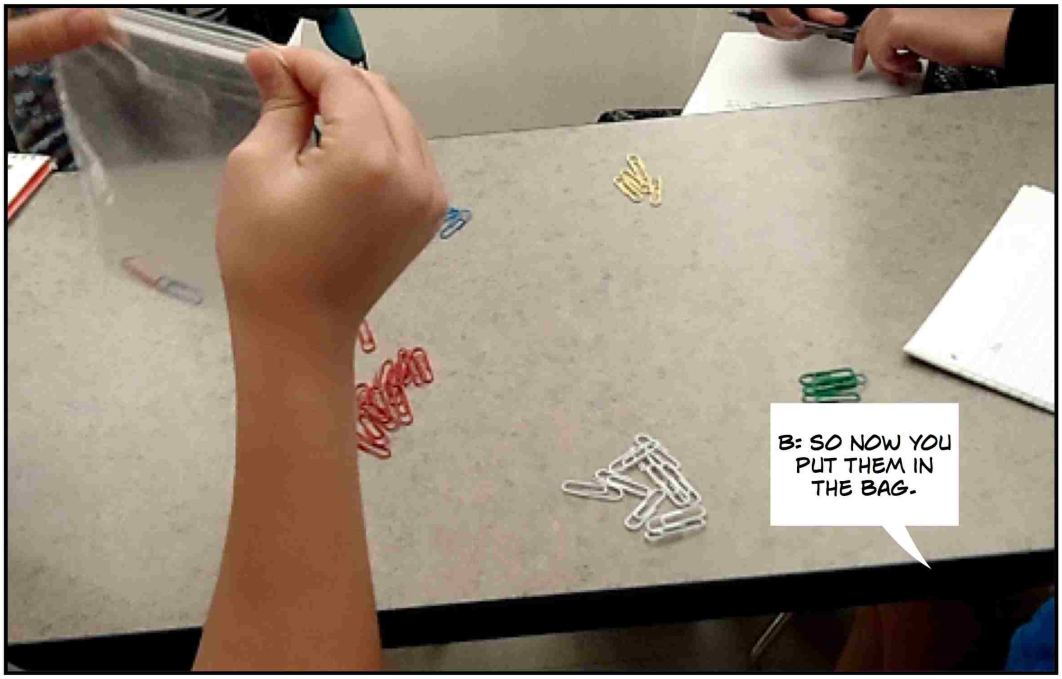

Figure 4.11 Annotated Scene 11

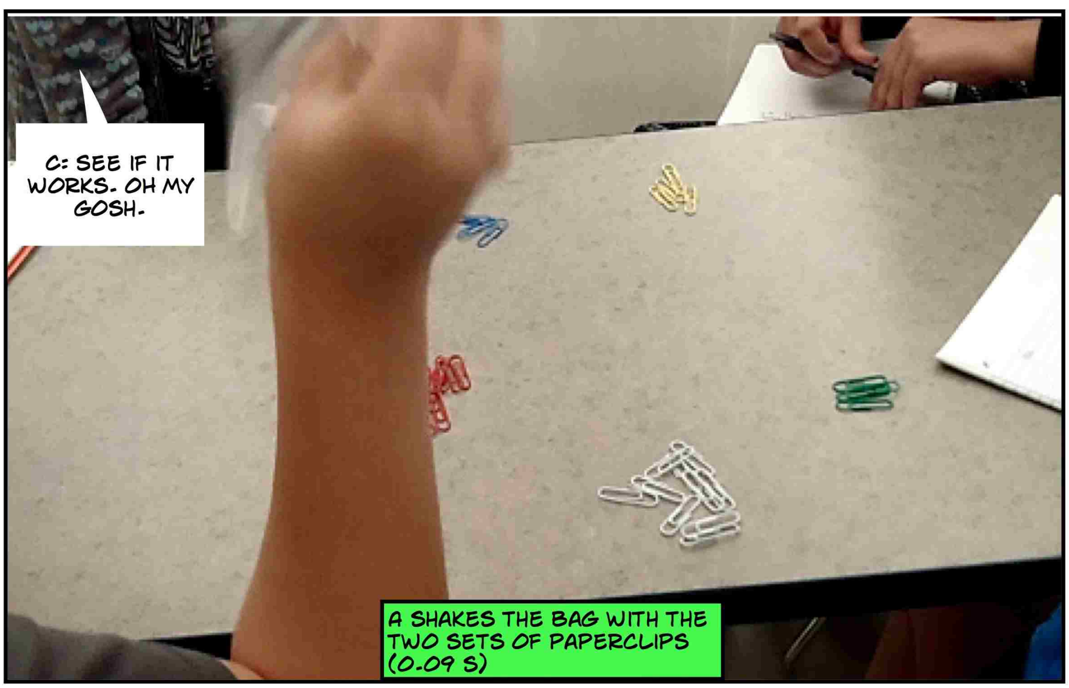

Figure 4.12 Annotated Scene 12

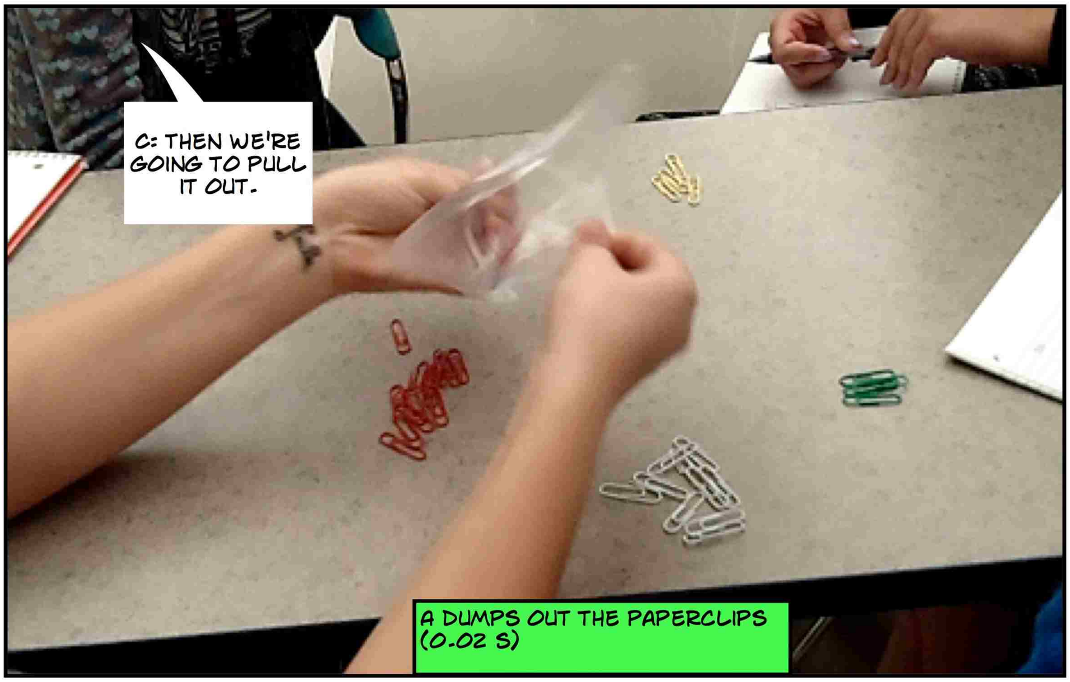

Figure 4.13 Annotated Scene 13

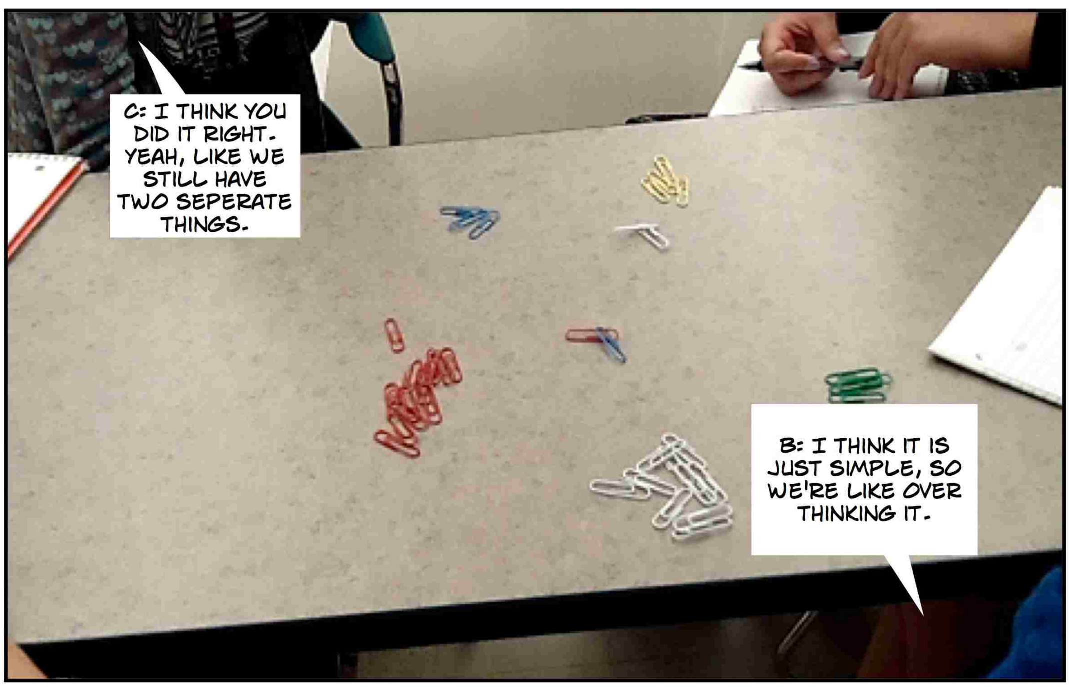

Figure 4.14 Annotated Scene 14

In Figure 4.11, Britney instructs Amanda to put both sets of paperclips into the bag. Amanda follows Britney's directions. In Figure 4.12, Carissa expresses sarcasm when she says, "See if it works, o my gosh." while Amanda shakes the bag. In Figure 4.13, Carissa instructs Amanda to pull out the paperclips and Amanda dumps the paperclips out of the bag onto the table.

The reason for putting the paperclips into the bag was to represent a mixture being created. The group engages procedurally with this concept about the mixture. The groups accurately carries out the procedure, but they do not understand why this procedure is being used. This type of procedural engagement looks different than the procedural engagement we saw with the directing frame. Here the students are creating their own ideas and orienteering themselves to understand the procedure, rather than the concepts. In Figure 4.14 Carissa and Britney agree that the group has accurately represented a mixture. While the group is discussing this, the instructor walks by the group. Britney asks the instructor if they are carrying out the activity correctly (Figure 4.15).

Orienting

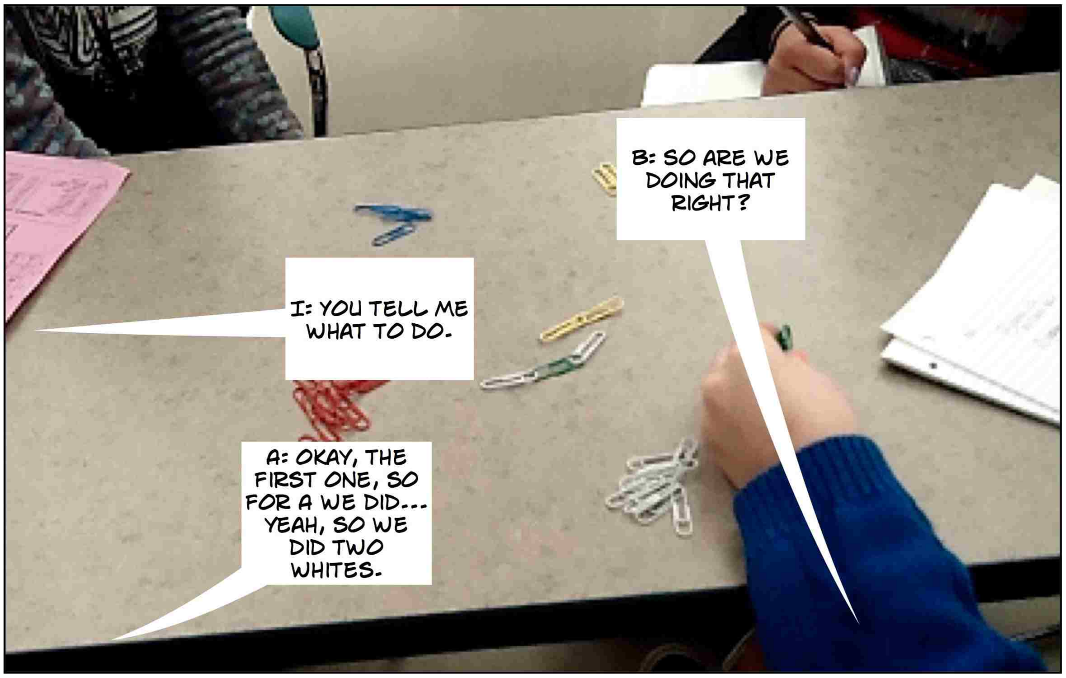

Figure 4.15 Annotated Scene 15

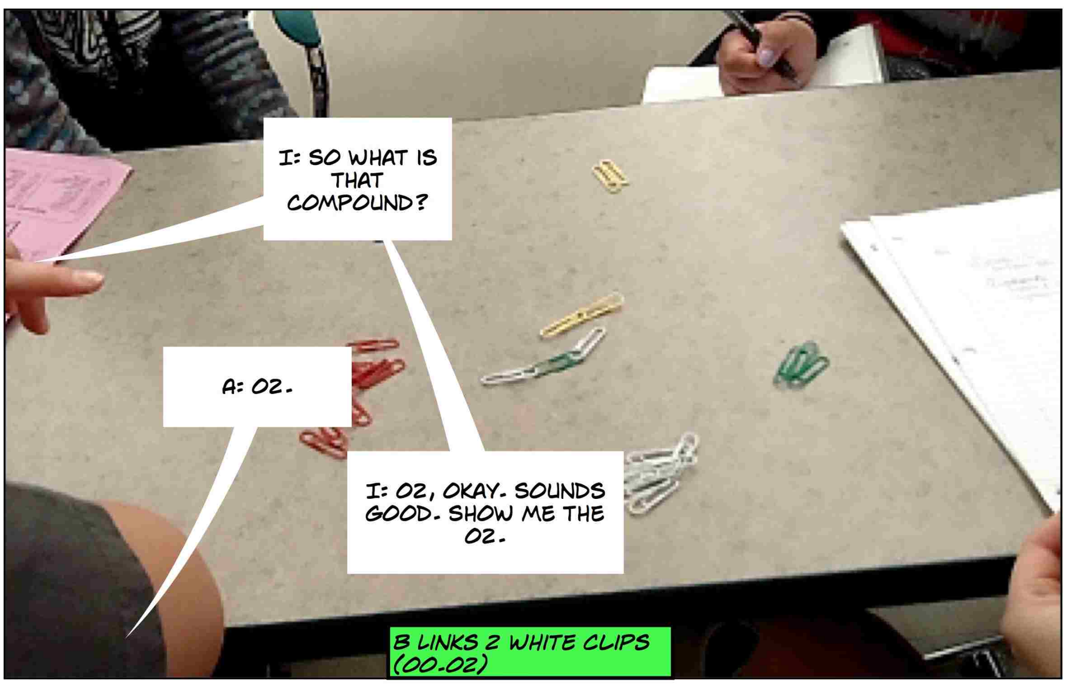

Figure 4.16 Annotated Scene 16

Figures 4.15 and 4.16 show the instructor orienting the students to the task. The students ask if they have answered the question correctly. Instead of just informing the students that they are correct or incorrect, the instructor asks the students to tell her what they did. The students then provide the answer to the instructor's question (they created O_2 using two white paper clips, which represents their molecular element). The instructor asks them another question that makes the students explain more about what they did. The instructor is consistently uses the answer the students provide to guide the response she gives back to the group. When the instructor forces the students to explain their process, it helps the students orient to the concepts being taught. After the students have explained what they have created, the instructor confirms that they are correct and asks them to build the representation with paperclips.

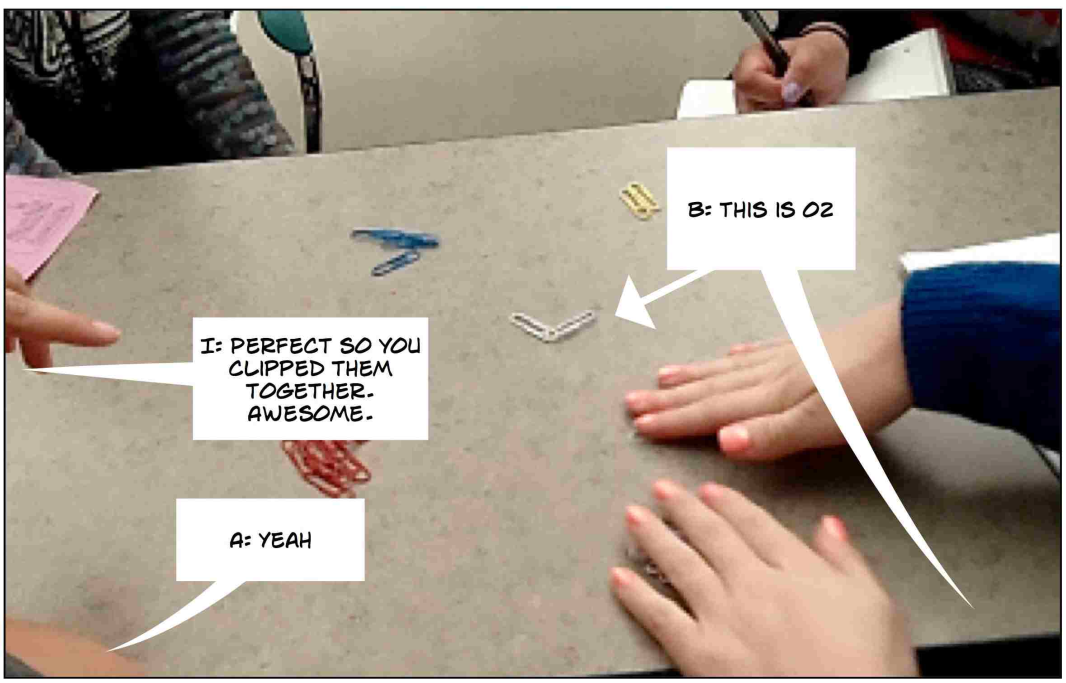

Figure 4.17 Annotated Scene 17

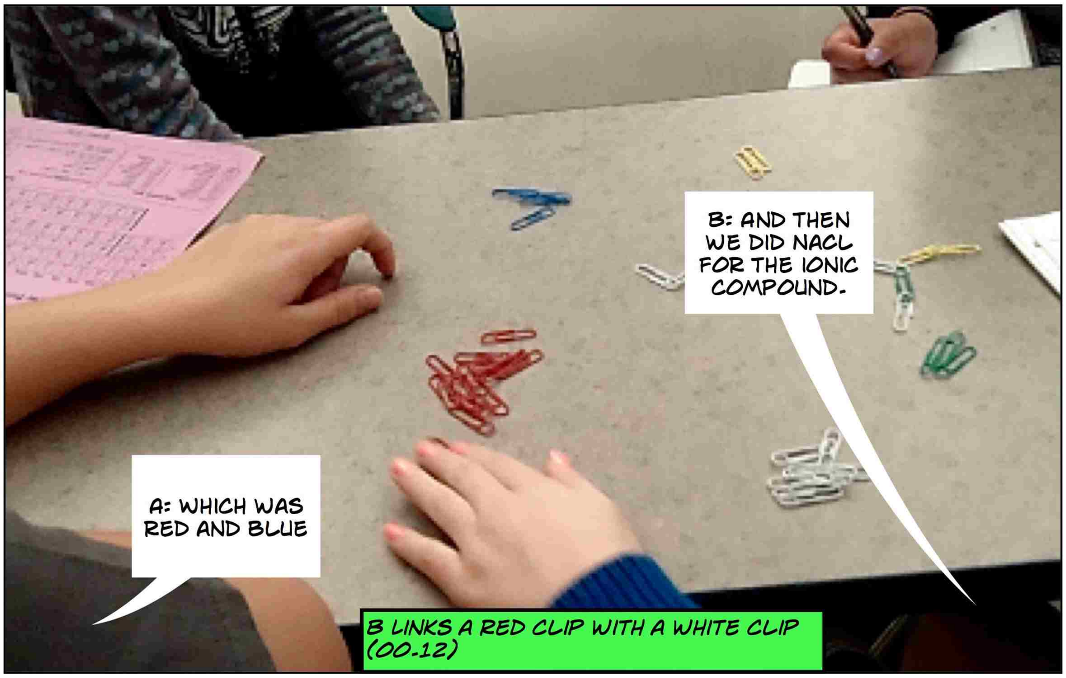

Figure 4.18 Annotated Scene 18

In figure 4.17, the students build their representation of O_2 and the instructor confirms that it is correct. The instructor also comments to the group that they have linked the paperclips together and she praises that they have done this action as well ("Perfect, so you clipped them together, awesome."). Linking the paperclips together will be an important step later in the activity, so the instructor is trying to emphasize that it was an important step. In Figure 4.18, the students build the other representation that must be created. During the process, the students explain to the instructor what they are creating and what they are using to create it (they create the compound NaCl using one red clip and one blue clip). This activity continues in Figure 4.19.

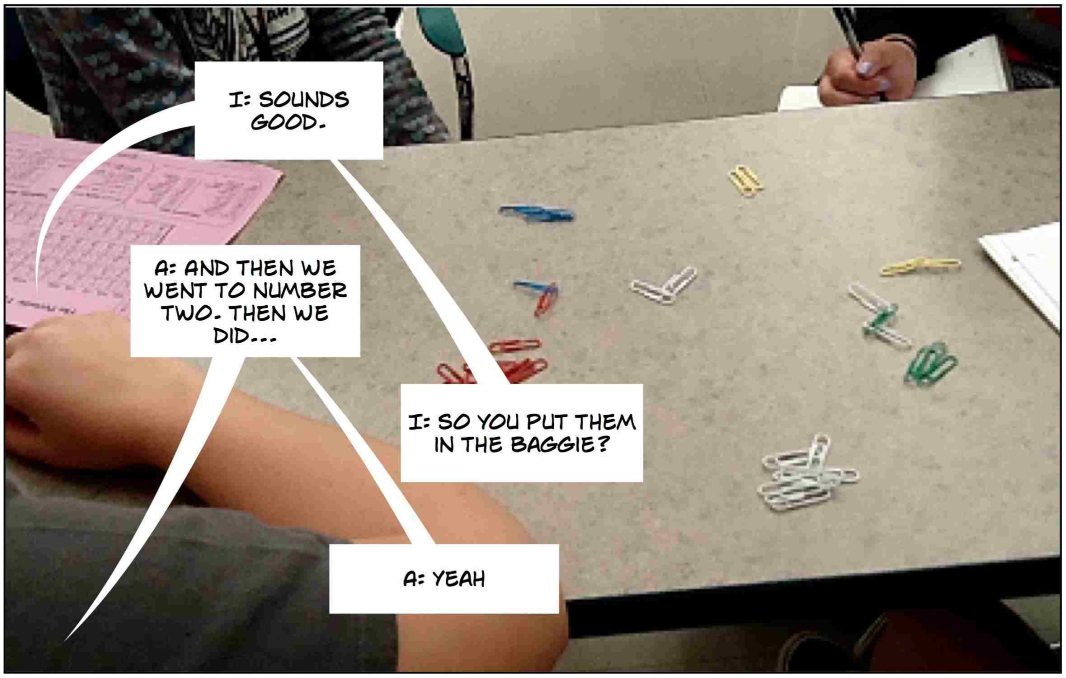

Figure 4.19 Annotated Scene 19

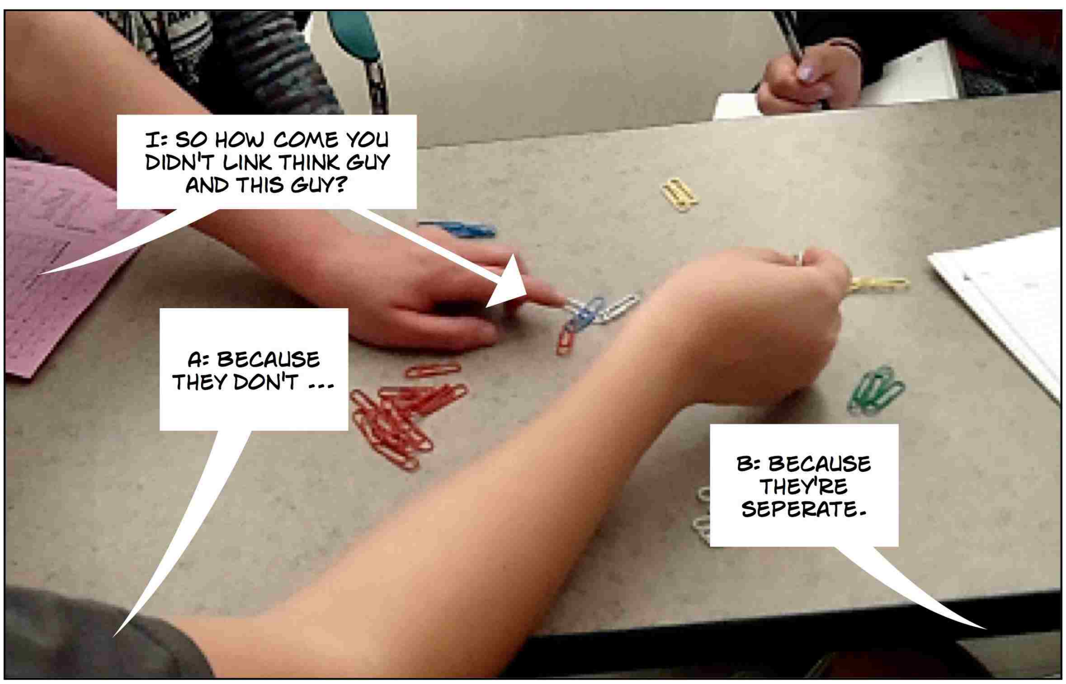

Figure 4.20 Annotated Scene 20

In Figure 4.19, the instructor confirms that the group is correct in their representation and because the group explained their process, the instructor did not ask any further questions. At this point, the students want to move onto the next problem, but the instructor requires them to explain their final step. The instructor asks the group if they put the paperclips into the baggie. Here the instructor is orienting the students from a procedural to conceptual form of engagement. In Figure 4.20, the instructor then asks them to explain more about what happened when they took the paperclips out of the bag. Recall that in Figure 4.17 the instructor praised them for linking them together and here she asks them to explain why they did not in this case. The students' responses show a clear understanding of the concept that the two different molecules are not linked because they are separate from one another. She explains this in Figure 4.21.

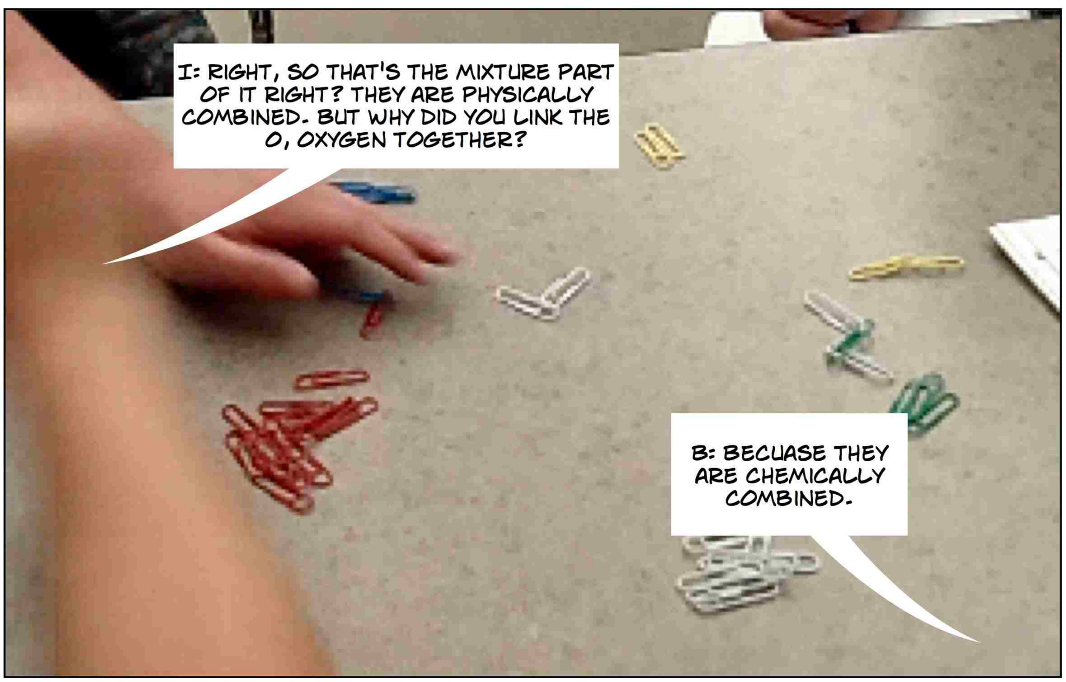

Figure 4.21 Annotated Scene 21

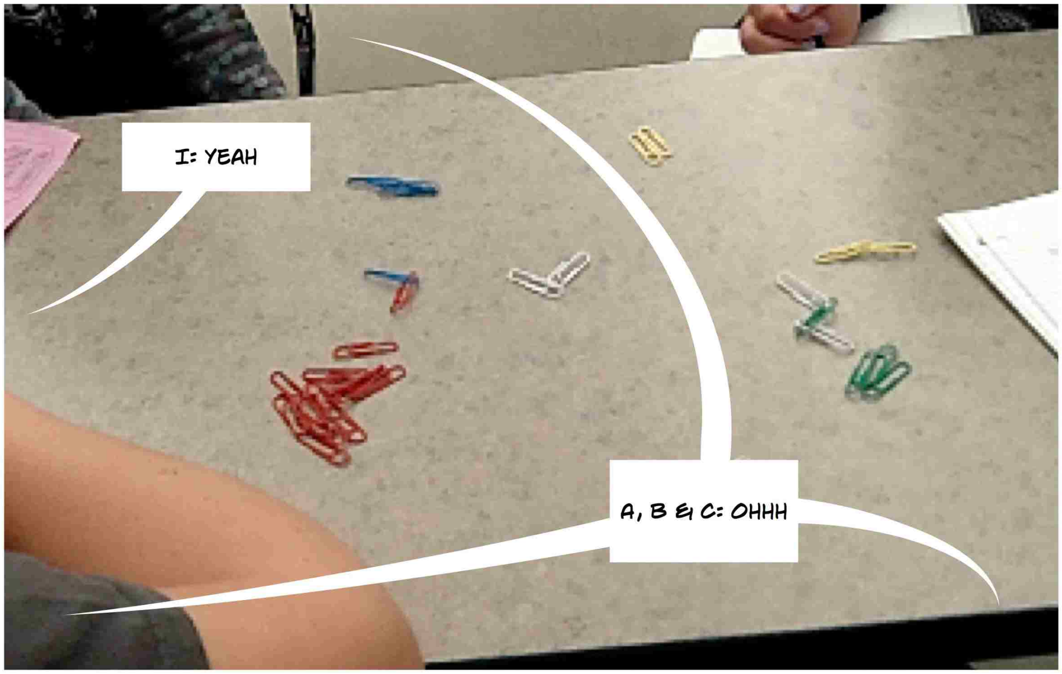

Figure 4.22 Annotated Scene 22

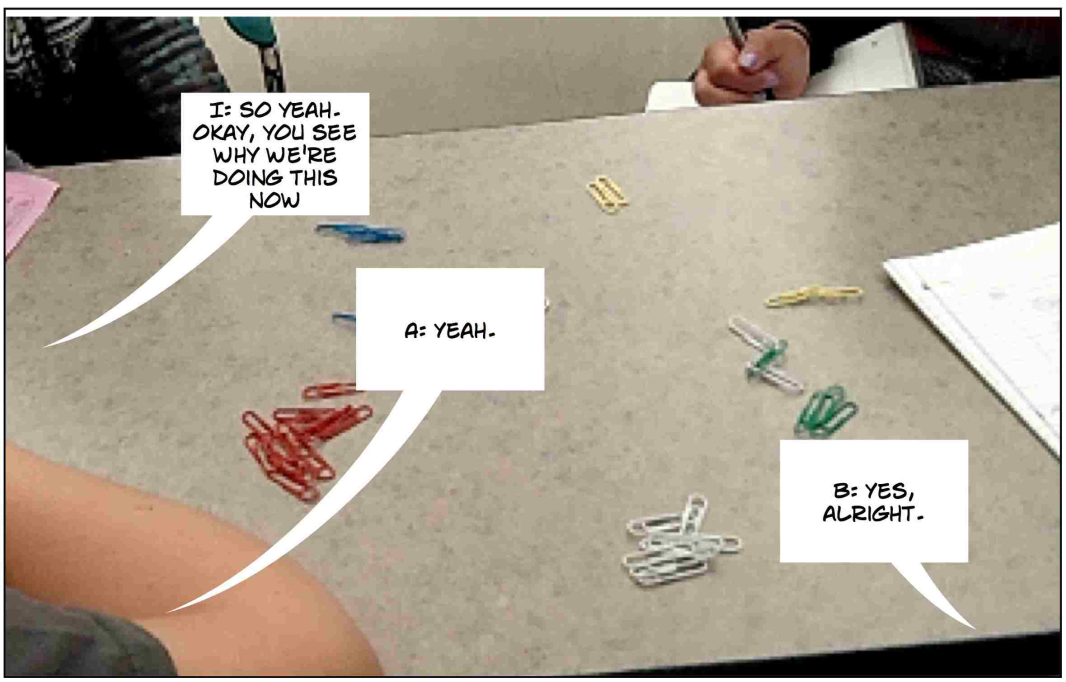

Figure 4.23 Annotated Scene 23

In Figure 4.21, the instructor builds on the understanding that molecules are physically combined and that is what makes it a mixture. She then follows with another question. This question orients the students' understanding that the paperclips that are linked are chemically combined. This is a clear example of orienting. The teacher understands that the students know the concept in a procedural manner; they can define the different between a chemical and a physical property. She engages the students in a conceptual manner by having them make the connection and understand how concepts relate to one another. In Figures 4.22 and 4.23, the students express that they fully understand the connection and have engaged in a conceptual manner. The instructor leaves and the students discuss their understanding (Figure 4.24).

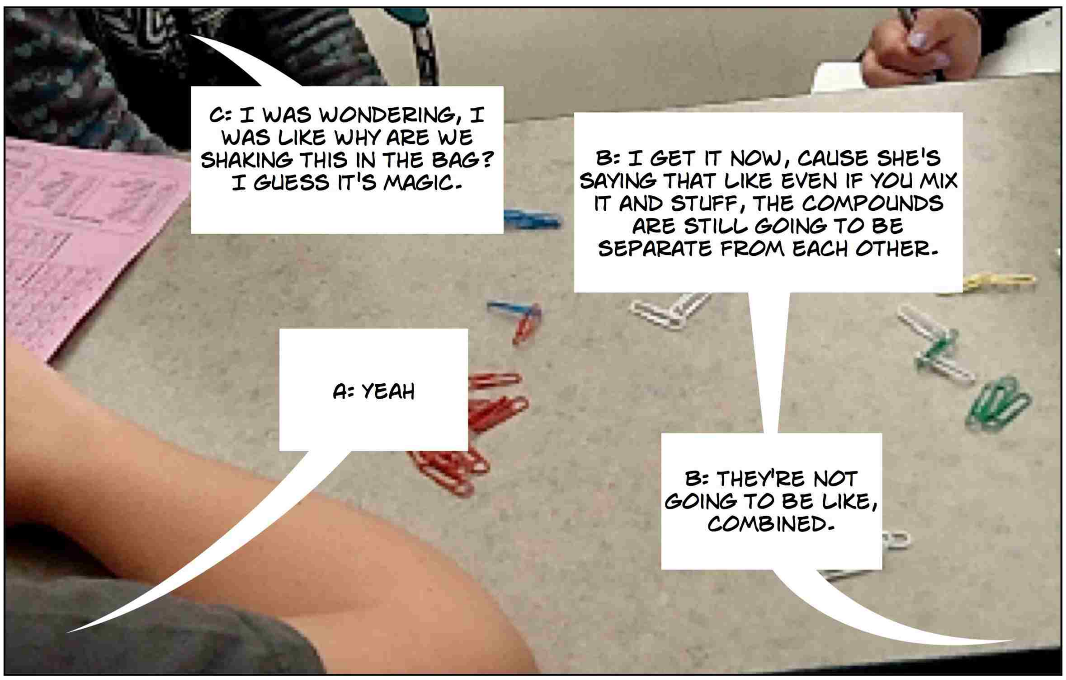

Figure 4.24 Annotated Scene 24

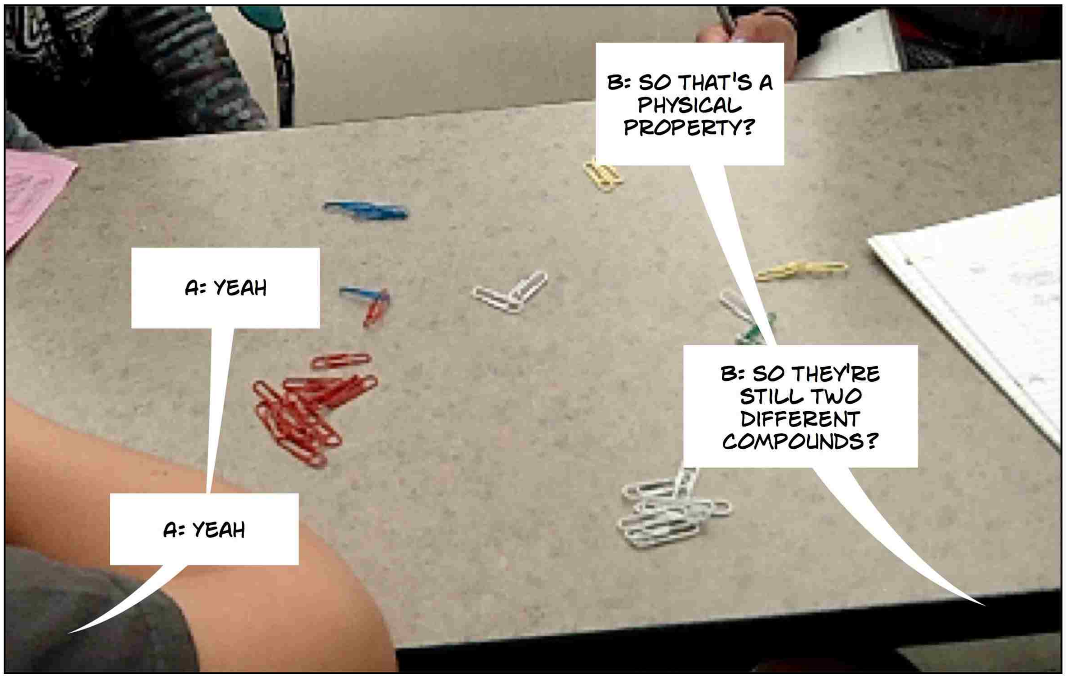

Figure 4.25 Annotated Scene 25

Figures 4.24 and 4.25 show the students discussing how these concepts relate to one another. Carissa explains that before the instructor oriented them, she did not fully understand what was happening. This orienting frame supported them to engage in a conceptual manner. When Britney explains, “Even when you mix it and stuff, the compounds are still going to be separate from each,” it is clear that she understands these concepts.

The Connection Between Orienting and Conceptual Engagement

Prior to the instructor’s orienting, the students engaged in a procedural manner. After she oriented them, they could define the concepts and accurately represent them; they understood how the concepts related to one another and explain why. This shows conceptual engagement. These annotated scenes also show that the teacher in not directing the students to the correct answer. Instead, she is having them explain what they understand and then she orients them by asking questions to guide them in their understanding. This process allows the students to create their own understanding and engage conceptually, not just procedurally.

Case 3: Orienteering with Paperclips

Orienteering is seen while the students engage in another paperclip activity. The goal of this paperclip activity is to have the students balance chemical equations. The activity is intended to involve using the paperclips to represent the chemical reactions that are given in each problem by building the reactants that are given and using those to create the products. A worksheet is provided for them to record their work. A key (Figure 4.26) is provided for the annotated scenes that depict the conversations and actions that four students had while orienteering (Figure 4.27 – Figure 4.36). This group of students was working on the first problem on the worksheet (Figure 4.27).

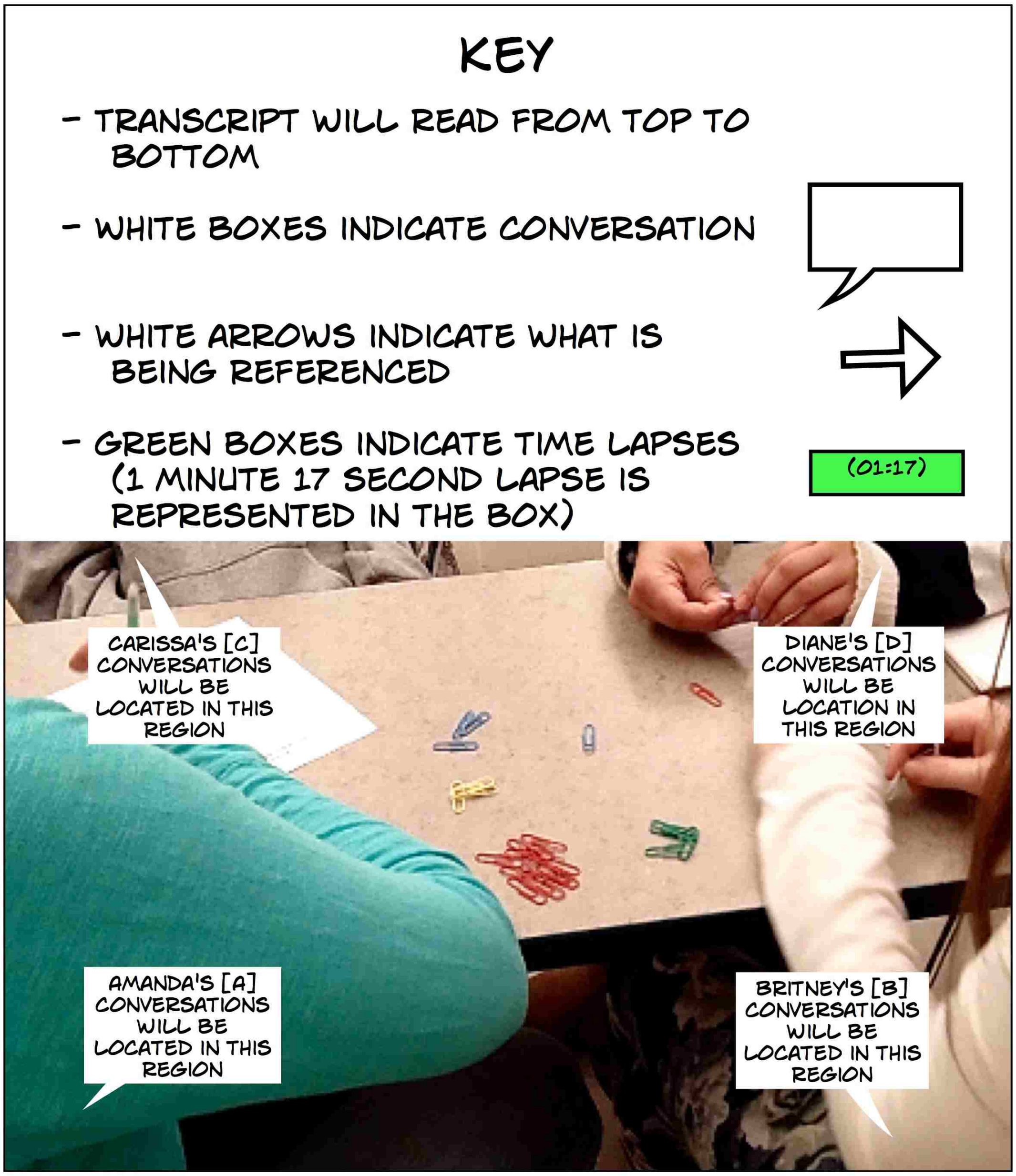

Figure 4.26 Key for understanding the annotated scenes.

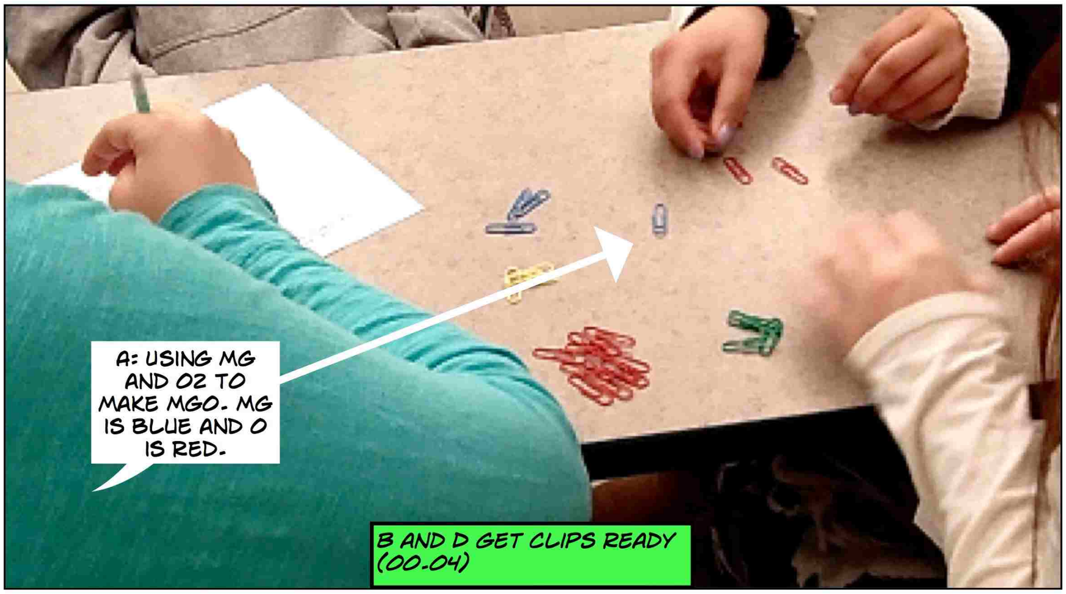

Figure 4.27 Annotated Scene 26

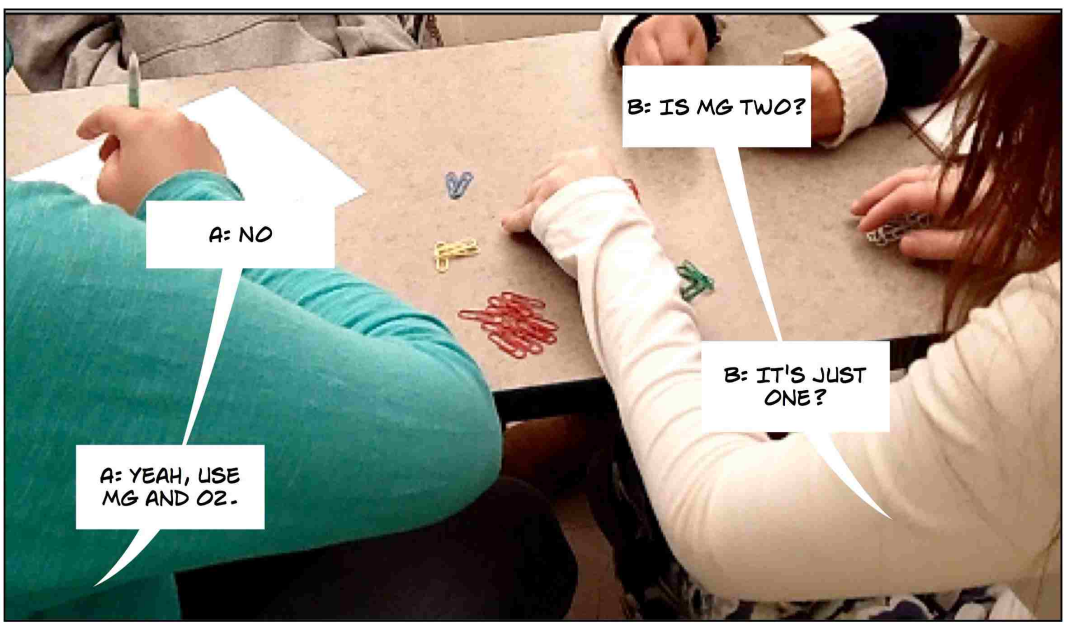

Figure 4.28 Annotated Scene 27

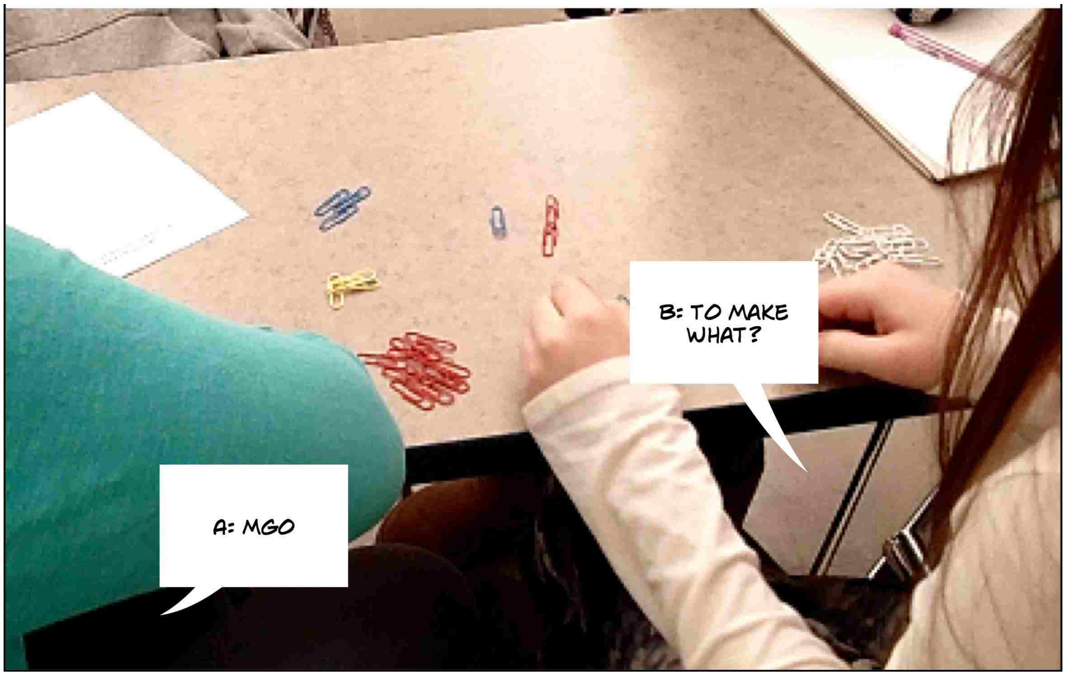

Figure 4.29 Annotated Scene 28

In Figure 4.27, Amanda reads the problem to the group to let them know what equation the group is trying to balance. In Figures 4.28 and 4.29, Britney is asking questions about what she is supposed to be creating and Amanda is providing her with the answers. Here the students are orienteering themselves in understanding in what they are trying to do and how to represent it with paperclips. Amanda has answered Britney's question and we see in the next scene that Britney understands.

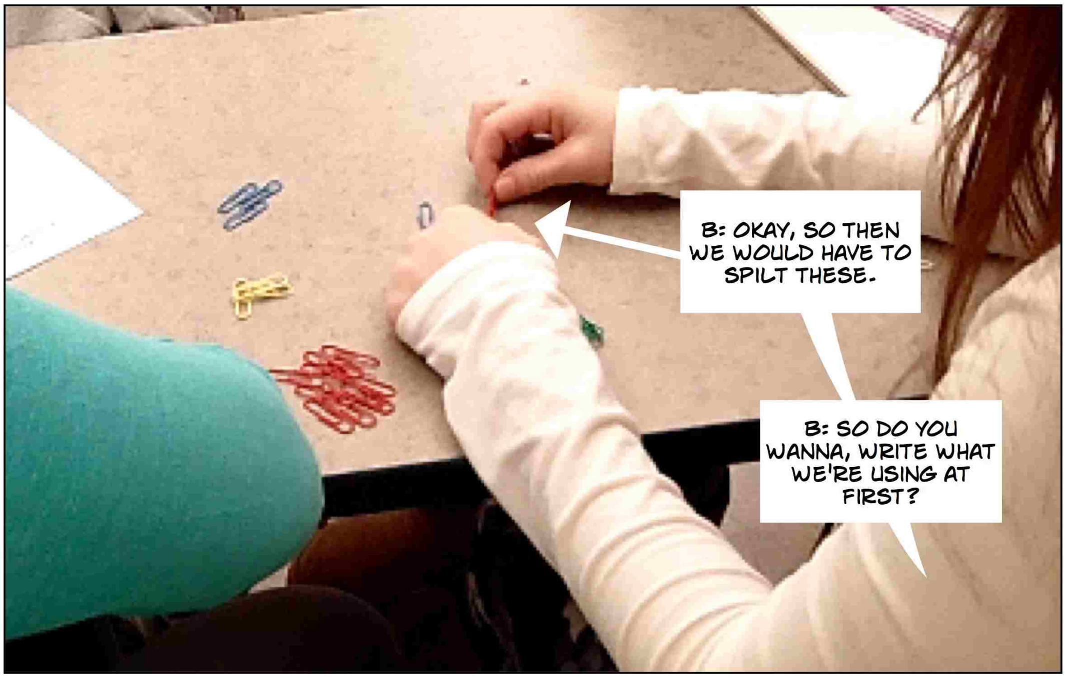

Figure 4.30 Annotated Scene 29

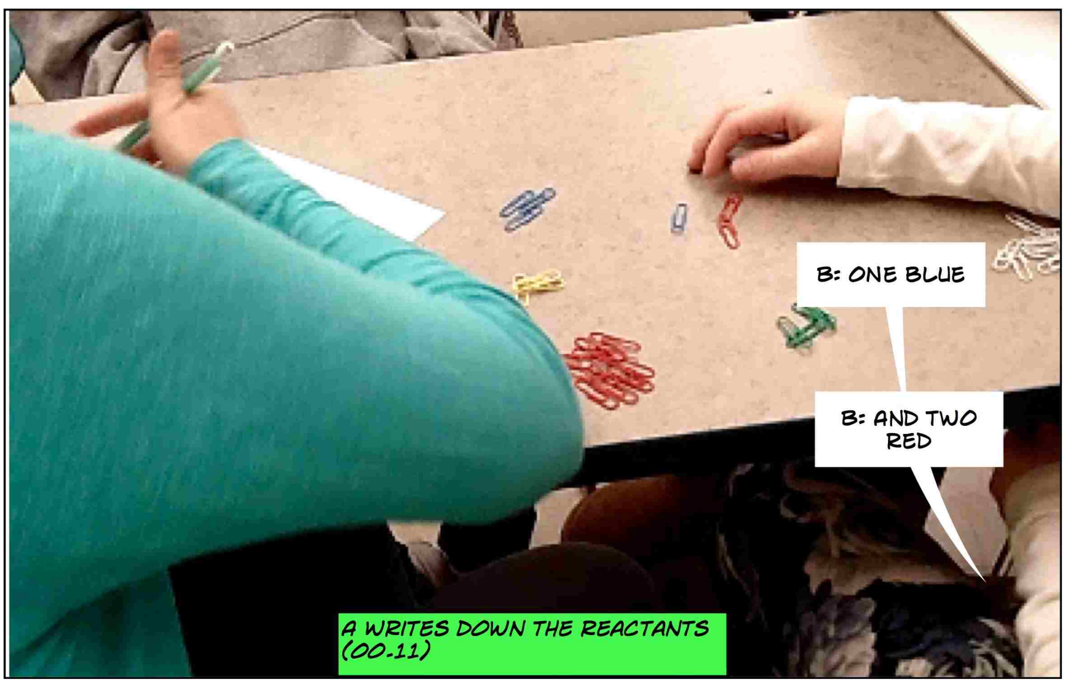

Figure 4.31 Annotated Scene 30

In Figure 4.30, Britney starts to move on to the next step, but then asks Amanda if she wants to record the reactants that they have created. In Figure 4.31, Amanda records the answer while Britney repeats what paperclips were used to create their reactants. Here, Britney and Amanda work together to make sure they have created the correct molecules and have the answer recorded properly. At this point, the group has carried out the procedure and they understand why it is correct. Amanda has recorded the correct answer and we see Carissa and Britney start creating the products in the next scene (Figure 4.32).

Figure 4.32 Annotated Scene 31

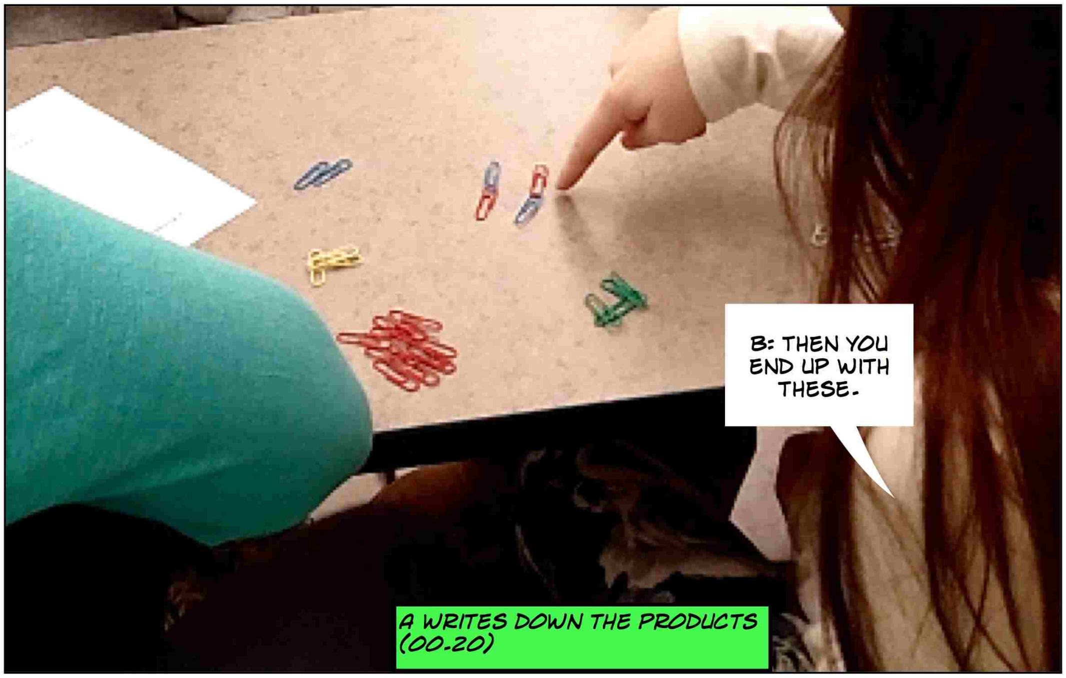

Figure 4.33 Annotated Scene 32

In Figure 4.32, Carissa says that they need to add one blue paperclip for the next step. Britney confirms this and links the paperclips together to create the product (Figure 4.33). Again, the students orienteer with each other to solve the problem. Carissa suggests what to do and Britney confirms it. The group agrees on the answer and starts to balance the equation in the next scene (Figure 4.34).

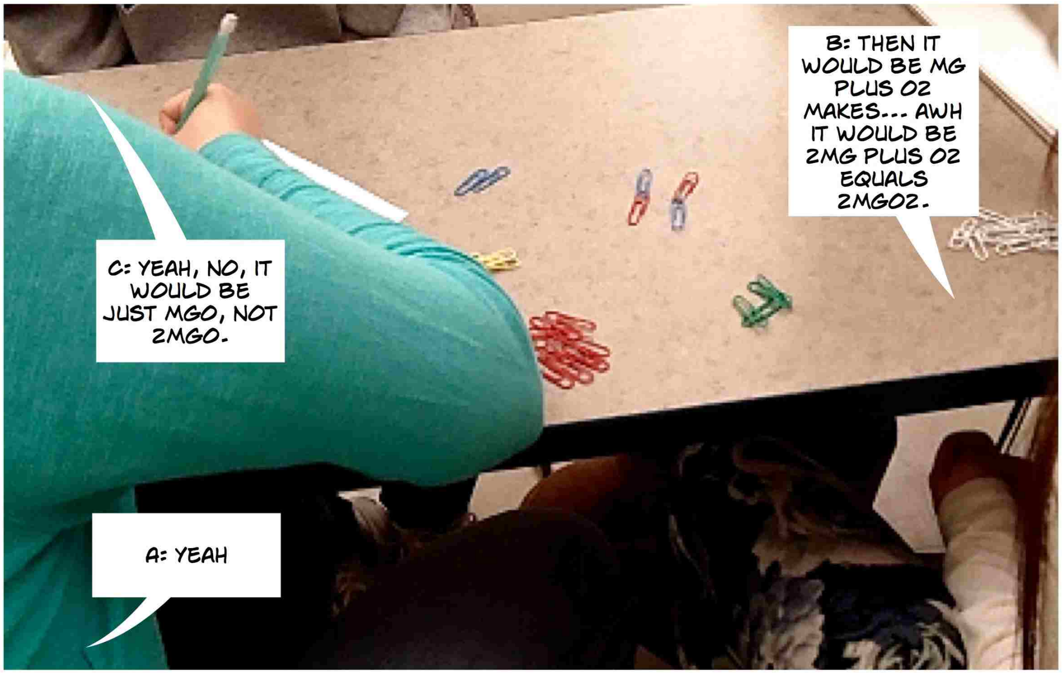

Figure 4.34 Annotated Scene 33

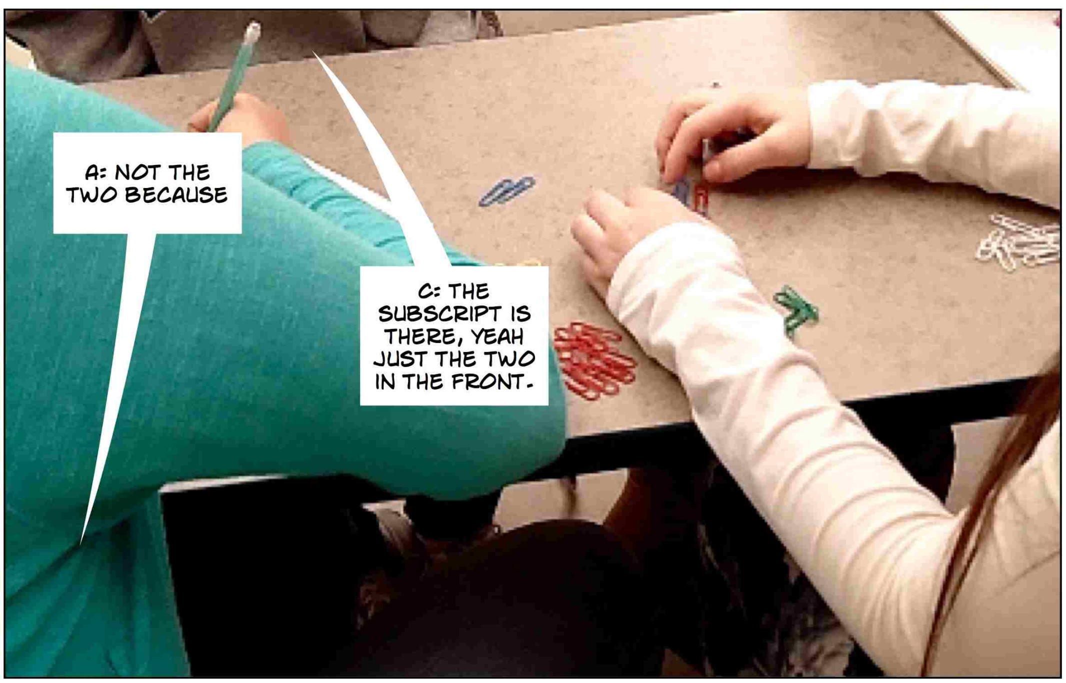

Figure 4.35 Annotated Scene 34

Figure 4.36 Annotated Scene 35

In Figure 4.34, the group is trying to write down the balanced equation. The group has already used the reactants to create the products and now has to record their answer. Britney states what she thinks the answer should be. Carissa agrees at first, but then disagrees. Carissa then suggests what the answer should be changed to. Amanda agrees with Carissa's answer. In Figure 4.35, Amanda and Carissa explain why the change must be made. Then in Figure 4.36, Britney expresses that she understands where she made her mistake. In these annotated scenes, the group does not agree on the same answer at first. The initial answer that is provided is rejected and a new answer is suggested. The group orienteers together and arrives at an answer that they all agree with.

These annotated scenes depict how the students orienteer themselves through the problem that they are trying to solve. Through this process the group works together to create an understanding and attempts to make sense of what they understand about the concept. The group is uninhibited by a teacher directing them to an answer or orienting them to an understanding the concept. Because there is not a teacher present, the students had to explain their answers to each other and create their own understanding. This sense-making process allows the students connect what they know about a topic and understand a new concept that is framed by their own ideas and orientations. The students have shown that they have engaged in both a procedural and conceptual manner. I don't see consequential engagement here. Consequential engagement would have involved students being able recognize that the ability of the reaction to occur is dependent on the amount of product that is present and if they were able to connect when it is appropriate to use without being prompted by the task. The task itself oriented the students, reducing the ability of the students to engage in a consequential manner.

Case 4: Disrupting Directing and Orienting with DomeStroids

In the final case, I present another example of directing and orienting, this time *disrupted.* Like in the cases previously presented, the instructor was directing and orienting the class through an activity. An important difference from the previous activities was that this activity took place in an immersive, interactive dome. As the students were participating, something interesting happened. A student named Ignacio, (a pseudonym), who had been struggling in class and had all but stopped participating, became consequentially engaged. I call this a *disruption* because it disrupted a habituated pattern of non-participation, and because it disrupted the patterns seen in Cases 1 and 2.

The goal of the DomeStroids activity is for the students to learn about arithmetic and geometric sequences. The students were introduced to the topic in a previous lesson, but they had not yet used equations with these concepts. This activity was structured to create a situation where there would be a need to develop an equation to help them solve the problem. The problem that the students are faced with is twenty asteroids are headed for earth. They must use a specialized weapon to minimize the asteroids before they enter the Earth's atmosphere. Each time an asteroid is fired upon, it splits into three pieces and each piece must be hit six times to reach minimum size. The students must figure out the number of times the weapon must be fired in order for all of the pieces to reach minimum size. An immersive, interactive projection was used to display the simulation (Figure 4.37).

Figure 4.37 The photograph above is of the immersive, interactive projection, with Mr. DiMaggio directing the students.

The following transcript is the conversations and activities that took place during this activity. The transcript includes the teacher, Mr. DiMaggio, and four students: Frank, Ignacio, Kristen, and Brian (all pseudonyms). The transcript begins after the teacher instructs the students on their tasks. Their roles have been assigned and students have had a chance to familiarize themselves with the interactive projection equipment.

Mr. D: So let's actually do this. Let's just fire it, take a snap shot, and then fire at another one, take a snap shot, and fire at another one, and stake a snapshot. That way we can get a sense of how many asteroids we have after we fire a couple of times. ((31s))

((Frank fires at an asteroid.)) ((2s))

Mr. D: Okay so… ((3s))

Ignacio: There's three so...((2s))

Mr. D: Kay press ‘A' to save the snapshot. Kay. Now, we're going to find another asteroid, fire again. ((17s))

((Frank fires at an asteroid again.)) ((3s))

Mr. D: Okay so that broke into three as well, right? So is there any way, let's try one more then save another snapshot. ((9s))

((Frank fires for a third time.)) ((2s))

In lines 1-13, Mr. DiMaggio is directing the students though the beginning steps of the activity. First, Mr. DiMaggio tells the students that they should start by shooting an asteroid and then take a snapshot of what has happened. The students follow these instructions and repeat this action a couple of times. Here the students are being directed and are just following the instructions provided for them. Mr. DiMaggio does not ask them to suggest any ideas nor is he asking questions that require the students to make connections between the concepts.

Mr. D: Okay again, broke into three. So let's see how many asteroids we had after each of those break. So, we started of with 20, and then we fired once, what happened? ((10s))

Ignacio: Split into 3. ((2s))

Mr. D: Okay, so how many did we have then? ((2s))

Ignacio: 23. ((1s))

Mr. D: Did we have 23? Well, cause 1 became 3, right? So actually we only added ... ((7s))

Kristen: 2. ((1s))

Mr. D: 2 more, so how many did we have? ((2s))

Kristen: 22. ((1s))

Mr. D: 22 Okay and then we did it again, we fired again. How many did we after that? ((6s))

Ignacio: So, would there be. A formula would be like, uh, the number of asteroids minus… minus one when it splits into three.

Mr. D: You're getting kind of the right idea; I'm not sure what you're saying. ((3s))

Ignacio: Minus 1 times 2. ((3s))

Mr. D: No not times 2. //

Ignacio: //Plus 2. ((2s))

Mr. D: You're almost there, you're almost there. Can anybody help him out? What do you guys think the formula for this thing should be?

In lines 14-26, Mr. DiMaggio is still directing the students through the activity. Here Mr. DiMaggio has started to ask questions about what is happening. Instead of asking the students to explain what has happened, he explains what happens and just has the students provide a ‘fill in the blank answer.’ This type of engagement does not allow the students to create their own understanding; Mr. DiMaggio is just directing them to what they need to understand.

However, in lines 27-28, the directing frame is disrupted; Ignacio expresses that there must be some type of formula that can be used to explain what is happening. He disrupts the pattern of answering the simple questions posed by Mr. DiMaggio, who responds with a new approach: orienting. In Lines 29-35, Mr. DiMaggio approves Ignacio’s suggestion and asks him to explain more. Mr. DiMaggio is no longer directing the class through the activity; instead, he is orienting the class to provide ideas and help Ignacio through his suggestion.

Ignacio: Number of asteroids minus 1. ((3s))

Mr. D: Everybody see what he's saying? Any… anybody maybe we can try and help him. ((5s))

Ignacio: You have your fixed amount is 20. //

Mr. D: //uh-huh//

41 Ignacio: And then you get your number of asteroids. And since you know it's
42 3, but you're subtracting 1, so it would be like you are losing that
43 last particle. ((12s))

44 Mr. D: Yeah, so how can we write a formula. What does that sound like? I
45 mean he's got the right idea, right? That's what's happening. ((5s))

46 Kristen: It sounds like a proportion, uhhh… ratio. ((2))

47 Ignacio: It's an equation. ((1s))

48 Mr. D: No::o, not quite a ratio. But it is an equation that deals with...so
49 what did we do? ((7s))

In Lines 50-58, the students try to figure out a formula. Here Mr. DiMaggio orients the students by guiding them through the activity. Is no longer directing them to the answer, he is now letting them suggest their own ideas and then provides feedback to orient them in the right direction. ((23 s)

The conversation continues about what the equation should be. ((78s))

50 Ignacio: Okay, so we should just.... the number of asteroids plus 2. ((6s))

51 Mr. D: Awwh, no, that sounds promising. ((5s))

52 Ignacio: Cause you were saying, if it splits into 2… you have 1 asteroid and
53 it splits into 3, but your not counting the 3 parts you're only counting
54 2 extra parts cause the 1 is the original. And so it would be the
55 number of asteroids plus 2. ((15s))

56 Mr. D: Yeah, that sounds reasonable, anybody, do people believe that?
57 Does that make sense? ((4s))

58 Kristen and Frank: Yeah. ((1s))

In Line 50, Ignacio eventually arrived at the correct equation. The students worked together to figure out the equation and Mr. DiMaggio helped orient them along the way. In Line 51, Mr. DiMaggio agrees with what Ignacio suggests as the answer. In Lines 52-55, Ignacio explains why he believes his answer is correct. In Lines 56-57, Mr. DiMaggio suggests that Ignacio's answer sounds reasonable and he also asks the other students if they agree with it. The other students confirm that they agree with Ignacio's answer. Mr. DiMaggio has oriented the students to the correct answer and allowed for the students to ask question and make suggestions on what to do.

At this point, the students understand that there is usefulness for this equation and have engaged consequentially. At the beginning of the activity, the students were being directed by Mr. DiMaggio and were only engaging at a procedural level. They were able to provide an answer to the questions being asked, but did not understand why these procedures worked. When Ignacio suggested that there must be some type of formula that could be used, he disrupted a pattern of his own prior non-participation and engaged consequentially. He understood that the pattern of asteroid destruction that was occurring in the DomeStroids activity could be expressed by a formula. He was able to recognize the impact of the disciplinary content and connect different solutions to different outcomes. The students also engaged in a conceptual manner as they worked to create the equation for the problem. They understood why the equation would work and they also understood if they equation they suggested was correct or incorrect.

Cross-case Analysis

Across these cases, different frames of instructional and learning sequences and forms of engagement emerged during the learning experiences. The first case had only procedural engagement, but all others had at least conceptual engagement as well. Only the 4^{th} case led to consequential engagement. Each case and the type of engagement present are outlined in the table below (Table 4.1).

Table 4.2. Instructional and learning sequence frame and later form of engagement

Case	*Frame*	*Later form of Engagement*

Case 1: Traditional Science Instruction	Directing	Procedural
Case 2: Paperclips 1	Orienteering followed by Orienting	Procedural followed by Conceptual
Case 3: Paperclips 2	Orienteering	Conceptual
Case 4: Disrupting Directing and Orienting with DomeStroids	Directing followed by Orienting	Procedural followed by Consequential

In the first case, the teacher was directing the students though the activity and the students only engaged in a procedural manner. This activity is a very familiar scene in many classrooms. This does not allow the students to create their own understanding as to why certain procedures or terminologies are correct.

The second case began with orienteering framing, followed by orienting; this supported the students to engage first procedurally and then conceptually. They had an understanding of why procedures were used. Had they not sought help from the teacher, they would likely have remained at a procedural level. Likewise, had the teacher only directed them, it is not clear if they would

In the third case the students orienteered themselves though the activity. There was no teacher interaction and the students worked together to create their own understanding of the content. In this case, the students first engaged at a procedural and then conceptual level, even without a teacher orienting them.

The fourth case demonstrated directing until a student's question disrupted the framing; the teacher responded to this, and began orienting instead. I infer that the immersive, interactive dome provided a disruption that allowed a student to disrupt existing patterns, allowing the teacher to reframe; this allowed the students to engage consequentially.

All of these cases are different from one another, but three of them supported the students to engage conceptually, and only the fourth case supported consequential engagement. Consequential engagement is essential in developing STEM practices.

Chapter 5: Discussion, Conclusions and Implications

Discussion

This study sought to investigate the following questions:

- What frames of instructional and learning sequences support students to engage procedurally, conceptually, and consequentially? How might the metaphor of orienteering, orienting, and directing make these frames clear?
- How might immersive, interactive technology disrupt a directing frame?

Many of the current and future problems facing our nation demand workers who are highly trained in STEM fields. There has been an emphasis put on the development of STEM practices, because of the lack of highly trained workers for these STEM jobs (National Research Council, 2012; Common Core State Standards Initiative, 2010; U.S. Department of Education, 2009). Gresalfi & Barab's (2011) framework on engagement provides a clear aim at the fact that procedural engagement is not enough. To properly develop these STEM practices, consequential engagement must occur. However Gresalfi & Barab (2011) describe *stable* practices rather than nascent learning. It is not clear how to provoke specific forms of engagement, especially when learning is nascent, but one approach is scaffolding.

It can be difficult for teachers to enact scaffolding, even when it is intended. Bliss, Askew, and Macrae (1996) conducted a qualitative study that explored if the model of scaffolding used for acquiring everyday knowledge could be transferred to specialized school knowledge. They also sought to develop a taxonomy of scaffolding strategies used in math, science, and design and technology. Thirteen teachers who were working with 9 to 11 year old students were studied. Field notes, audio and video recordings, and interviews were collected. Their first findings revealed that scaffolding was absent in most lessons. The teachers reported that they were able to plan for scaffolding, but the implementation was difficult.

To investigate why this was difficult, they conducted another in-depth analysis, this time including detailed reasons as to why scaffolding was not present. Their conclusions from this study are that scaffolds can happen in school, but they are more difficult than initially believed to be. They argue that, "teachers need a more elaborate set of skills in assistance and they need to be more conscious of their application" (p. 60). To plan for these scaffolds, teacher must be able to identify how they can connect the student's understanding of a concept to the specialist's knowledge of that concept. Bliss, Askew, and Macrae (1996) also maintain that teachers must be content with the fact that students learn difficult and complex ideas in a step-by-step manner and the path must be negotiated between the student and the teacher

According to Bliss, Askew and Macrae (1996) directing "contains a substantial amount of 'teacher talk' with little or no room for 'pupil talk'" (p.46). Directing is teacher led and students simply 'fill in the blank' or give a brief response. Often there is little or no discussion around the understanding as to why a certain answer is correct.

In the first case, procedural engagement followed directing. Gresalfi & Barab (2011) define procedural engagement as, "using procedures accurately, but not necessarily with an understanding of why one is performing such procedures (p. 302).

Orienteering as a space for productive failure

In Case Two, the students first orienteered themselves through the activity and later were oriented by the teacher. Orienteering allows students to develop their own understanding by working with other students. In orienteering, it is common for students to arrive at the wrong answer. The students work together and try to find the best solution that they can, but often there is a mistake made. Even when mistakes are made, this can still provide benefits for the students in their learning.

Kapur & Bielaczyc (2012) worked with the framework of *productive failure*. This notion of productive failure is explained as, “designing conditions that may well not maximize performance in the shorter term but in fact maximize learning in the longer term” (p. 78). In this study, students either worked together to solve complex problems without any instructional support or scaffolds until a teacher-led discussion or had direct instruction with strong instructional support, scaffolds and feedback throughout the process. The students that worked without any instructional support failed in their problem-solving efforts, but they outperformed the other students on the well-structured and complex problems on the posttest. Likewise, orienteering may not always lead directly to conceptual or consequential engagement, but it may allow for students to engage later in a conceptual and consequential manner. For example in the second case, the students did not engage with the mixture concepts beyond a procedural manner when they were orienteering. They were unable to understand the why these procedures were used. However, when the teacher oriented the students, they were able to see where they had made their mistakes and engaged with the concepts in a conceptual manner. Their failure was productive because in supported their later learning.

Why immersive, interactive projection might serve as a disruption to habituated patterns

In Case 4, the immersive, interactive projection provided a disruption that supported Ignacio change the form of engagement from procedural to consequential. This disruption also supported the teacher to switch from directing the students through the activity to orienting with them through the activity. This allowed the students to develop a deeper understanding around the concepts being taught. Pea (2004) claims that, “Scaffolds are not found in software but are functions of processes that relate people to performances in activity systems over time” (p. 446). Immersive, interactive projection is a scaffold that supports these functions of processes very well.

There are many benefits that come from using immersive, interactive environments. They support factual and conceptual learning (Jacobson, 2010; Limniou, Roberts, & Papadopoulos, 2008) and create narrative and sensory presence (Dondlinger, 2007). Dede (2009) calls this experience, situated learning, and he argues that authentic contexts, activities, and assessments must be created to support narrative. An initial challenge, roles, a backstory, and challenges or puzzles can all be created to strengthen the narrative (Dickey, 2006). These environments can also provide many opportunities to support learning in ways that are not easily attainable in “real-life” situations, because they can be manipulated (Dondlinger, 2007). They can also serve as a mediator between virtual and real identities, engaging students previously uninterested and allowing them to take on roles they would have otherwise not assumed (Dunleavy, Dede, & Mitchell, 2009). When roles are created and a narrative is provided, it allows students to engage in multiple ways and supports the development of STEM practices.

Conclusions

Video data and field notes were collected to capture what was occurring during learning experiences. Data were transcribed and later analyzed using interaction analysis. From this data, multiple case studies were created to develop the frames of directing, orienting, and orienteering.

Directing was seen in the first case and the teacher demonstrated a practice that is very common in many traditional classrooms. The teacher directed the students to the correct answer and did not support the student to engage beyond a procedural manner with the concepts. When a student provided the correct answer, the teacher confirmed that it was correct and there was no further discussion. If students had an incorrect answer, they had no opportunity to understand why their answer was incorrect.

Orienteering followed by orienting was seen in the second case. The students first orienteered together started to create an understanding about the concepts. The teacher then came over to the group and helped orient them to a comprehensive understanding about the concepts. In this case, the students first engaged in a procedural manner and eventually engaged conceptually. The orienting from the teacher allowed the students to move from a procedural engagement to a conceptual engagement. If the teacher had directed them to the answer, conceptual engagement may not have happened.

In the third case the students orienteered themselves though the activity. There was no teacher interaction and the students worked together to create their own understanding of the content. In this case, the students first engaged at a procedural and then conceptual level, even without a teacher orienting them.

The fourth case demonstrated directing until a student's question disrupted the framing; the teacher responded to this, and began orienting instead. I infer that the immersive, interactive dome provided a disruption that allowed a student to disrupt existing patterns, allowing the teacher to reframe; this allowed the students to engage consequentially.

All of these cases are different from one another, but three of them supported the students to engage conceptually, and only the fourth case supported consequential engagement. Consequential engagement is essential in developing STEM practices. To support consequential engagement, multiple frames (directing, orienting, and orienting) along with disruptions in traditional instructional practices can be used.

Limitations

These cases studies are a small sample size and create a limitation to this study. Another limitation would be that there are only a few cases from which these findings have been drawn from. These limitations mean that generalizations cannot be made about the findings from this study. They are limited to these cases and need further research to support

Implications

For instruction and curricular design

Using a combination of these different frames of instructional and learning sequences (directing, orienting, and orienteering) supports the students to engage consequentially later. A traditional method of only directing the students to an answer does not lead to consequential engagement. Curricula must be designed with activities and lessons that allow student to engage consequentially. Curricula should also be designed to integrate immersive, interaction projection to allow the students opportunities to interact with material in novel ways that may also support consequential engagement. Teachers must not only design activities that support these frames of instructional and learning sequences, but they must also use them in their teaching. They have to incorporate these multiple frames and not direct students to the answer. They must orient the students through an activity and also allow students to orienteer themselves, even when students are struggling. Allowing them to develop their own understandings and develop a deeper understanding is will develop STEM practices.

Research

Further research is needed to explore the frames of instructional and learning sequences that I have outlined. Studies should include a lager number of participants and incorporate more activities. These activities should also be focused in many different content areas. This research should investigate the relationship between these instructional and learning sequences and what forms of engagement are supported later. Additional research should investigate other ways to support consequential engagement as well.

Methods

Comic Life 2 was used to create annotated scenes for video data that were collected. Using this software to create these annotated scenes could be a valuable tool for presenting data. Often it is difficult to express what is happening in an activity just though using transcripts and explaining what is happening. This software allows users to create annotated scenes using screen shots and overlaying it with transcript in conversation bubbles. This depicts the scene in a way that is very easy for the reader to understand what is happening in the activity. When transcripts include references that are ambiguous and are hard for the reader to understand what is happening, *Comic Life 2*, helps to provide more clear understanding. This software could be very helpful to future research that uses similar data collection and analysis methods.

References

Barron, B., & Engle, R. (2007). Analyzing Data Derived From Video Records. In S. J. Derry, R. D. Pea, B. Barron, R. Engle, F. Erickson, R. Goldman, et al. (Eds.), *Guidelines for Video Research in the Learning Sciences* (pp. 20-28): Journal of the Learning Sciences.

Barron, B., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A. J., Zech, L., et al. (1998). Doing with Understanding: Lessons from Research on Problem- and Project-Based Learning. *The Journal of the Learning Sciences, 7*(3/4), 271-311.

Bliss, J., Askew, M., & Macrae, S. (1996). Effective teaching and learning: Scaffolding revisited. *Oxford Review of Education*, *22*(1), 37-61.

Common Core State Standards Initiative. (2010). Common core state standards for mathematics. *Retrieved November, 11, 2013*.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*(5910), 66-69.

Derry, S. J., Pea, R. D., Barron, B., Engle, R., Erickson, F., Goldman, R., et al. (2010). Conducting Video Research in the Learning Sciences: Guidance on Selection, Analysis, Technology, and Ethics. *Journal of the Learning Sciences, 19*(1), 3-53.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development, 54*(3), 245-263.

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology, 4*(1), 21-31.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7-22.

Fraser, J., Heimlich, J. E., Jacobsen, J., Yocco, V., Sickler, J., Kisiel, J., . . . Stahl, J. (2012). Giant screen film and science learning in museums. *Museum Management and Curatorship, 27*(2), 179-195.

Gresalfi, M., & Barab, S. (2011). Learning for a Reason: Supporting Forms of Engagement by Designing Tasks and Orchestrating Environments. *Theory into Practice, 50*(4), 300-310.

Hall, R. (2007). Strategies for Video Recording: Fast, Cheap, and (Mostly) in Control. In S. J. Derry, R. D. Pea, B. Barron, R. Engle, F. Erickson, R. Goldman, et al. (Eds.), *Guidelines for Video Research in the Learning Sciences* (pp. 63-71): Journal of the Learning Sciences.

Hall, R. (2000). Videorecording as theory. In *Handbook of research design in mathematics and science education* (pp. 647-664). Mahwah, NJ: Erlbaum.

Hmelo-Silver, C., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107.

Jacobson, J. (2010). *Digital Dome Versus Desktop Computer in a Learning Game for Religious Architecture.* Paper presented at the AERA.

Jacobson, J. (2012). Interaction Beyond the Desktop. *arvelsig*. Retrieved from arvelsig.wordpress.com/2012/07/19/interaction-beyond-the-desktop/

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, *4*(1), 39-103.

Kapur, M., & Bielaczyc, K. (2012). Designing for productive failure. *Journal of the Learning Sciences, 21*(1), 45-83.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75-86.

Kyza, E. A. (2009). Middle-School Students' Reasoning About Alternative Hypotheses in a Scaffolded, Software-Based Inquiry Investigation. *Cognition and Instruction, 27*(4), 277 - 311.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments, 10*(3), 282-297.

Linn, M. C., & Slotta, J. D. (2000). WISE science. *Educational Leadership*, *58*(2), 29-32.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. In committee on conceptual framework for the new K-12 science education standards, board on science education & division of behavioral and social sciences and education. Washington DC: The National Academies Press.

Pea, R. D. (2004). The Social and Technological Dimensions of Scaffolding and Related Theoretical Concepts for Learning, Education, and Human Activity. *Journal of the Learning Sciences, 13*(3), 423-451.

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching*, *42*(2), 185-217.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., ... & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences*, *13*(3), 337-386.

Ragin, C., & Becker, H. (1992). *What is a case?: exploring the foundations of social inquiry.*

Ravitech, Diane. (210, September 1). Obama's Race to the Top Will Not Improve Education. *The Huffington Post.* Retrieved from http://www.huffingtonpost.com/diane-ravitch/obamas-race-to-the-top-wi_b_666598.html

Rudolph, J. L. (2005). Epistemology for the masses: The origins of "The Scientific Method" in American schools. *History of Education Quarterly, 45*(3), 341-376.

Sandoval, W., & Reiser, B. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education, 88*(3), 345-372.

Singer, J., Marx, R., Krajcik, J. S., & Clay Chambers, J. (2000). Constructing Extended Inquiry Projects: Curriculum Materials for Science Education Reform. *Educational Psychologist, 35*(3), 165-178.`

Solomon, J., Duveen, J., Scot, L., & McCarthy, S. (1992). Teaching about the nature of science through history: Action research in the classroom. *Journal of Research in Science Teaching, 29*(4), 409-421.

Svihla, V., & Linn, M. C. (2012). A design-based approach to fostering understanding of global climate change. *International Journal of Science Education*, *34*(5), 651-676.

U.S. Department of Education. (2009). *Race to the top program executive summary.* Washington, DC. *Retrieved April 3, 2013*.

Vygotsky, L. L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard university press.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving*. *Journal of child psychology and psychiatry*, *17*(2), 89-100.

Yin, R. K. (2003). *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage Publications Inc.