MIDDLE SCHOOL STUDENTS' LEARNING ABOUT GENETIC INHERITANCE THROUGH ON-LINE SCAFFOLDING SUPPORTS

By

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ABSTRACT

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The main goal of school science is to enable learners to become scientifically literate through their participation in scientific discourses (McNeill & Krajcik, 2009). One of the key elements of scientific discourses is the ability to construct scientific explanations that consist of valid claims supported by appropriate evidence (e.g., McNeill & Krajcik, 2006, Sadler, 2004; Sandoval & Reiser, 2004). Curricula scaffolds may help students construct scientific explanations and achieve their learning goals. This dissertation study is part of a larger study designed to support fifth through seventh grade students' learning about genetic inheritance through curricula scaffolds. Seventh grade students in this study interacted with a Web Based Inquiry Science Environment (WISE) unit called "From Genotype to Phenotype" that had curricula scaffolds. Informed by the Scaffolded Knowledge Integration, two versions of the unit were developed around concepts on genetic inheritance. Version one of the units was explicit on explaining to students how to make a claim and support it with appropriate evidence. Although the science concepts covered were the same, Version two was not explicit on claims and evidence use. Embedded in the units were scaffolding supports in the form of prompts. This dissertation study explored students' responses to the scaffolding support prompts using a knowledge integration (KI) rubric as described by Linn and His (2000).

Two teachers, each with about 150 students in five classes of about 25 each, participated in the study. Each teacher had three classes of students that received a version one and the other

two classed received version two of “From Genotype to Phenotype” unit. Using the Statistical Package for Social Scientists (SPSS), I explored whether students’ scores, as measured by the KI rubric, varied by the unit version the students received or by the teacher they had. The findings suggested that the two versions of the unit were equally valuable as there were no significant differences in test scores between students who interacted with different unit versions, $F(1, 141) = 3.35$, $p = 0.07$. However, there was a significant difference between test scores of students who had different teachers, $F(1, 141) = 12.51$, $p = 0.001$.

Furthermore, apart from scoring for scientific accuracy, responses were also examined to establish whether students held some of the conceptions reported in literature about genetic inheritance. Where possible, attempts were made to identify whether students were using evidence from the unit or their out-of-school experiences in their responses to the scaffolding support prompts. It was evident that about half of the students attributed most of their inherited traits to a specific parent they resemble for that trait. In this dissertation study, the term *students’ resemblance theory* was used to refer to the aforementioned students’ reasoning. Additional, I argue that *students’ resemblance theory* may be used to explain students’ thinking when they incorrectly believe that boys or girls inherit more genes from their father or mother based on gender resemblance. Consequently, I argued that *students’ resemblance theory* may influence students’ learning and understanding about Mendel’s law of segregation which include the following principles; genes exist in more than one form, offspring inherit two alleles for each trait, allele pairs separate during meiosis and alleles can be recessive or dominant. This study documented students’ conceptions related to Mendel’s law of segregation.

DEDICATION

In memory of my grandparents James and Rhoda, my father John (who passed when I was writing my dissertation) and my brother Robson

To my mother Cecilia for her patience and support

To my auntie Emilia who has always been there for me

To my husband Maxwell and our daughters Nyasha, Angela and Clare for being there as I pursued my dreams

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CHAPTER 1

INTRODUCTION

According to the American Association for the Advancement of Science (AAAS), scientific literacy may be broadly defined as the ability to make connections between science ideas in addition to the acquisition of scientific world view and methods of inquiry (AAAS, 2009). Consequently, the main goal of school science is to enable learners to become scientifically literate through their participation in scientific discourses (McNeill & Krajcik, 2009). One of the key elements of scientific discourses is the ability to construct scientific explanations that consist of valid claims supported by appropriate evidence (e.g., McNeill & Krajcik, 2006, Sadler, 2004; Sandoval & Reiser, 2004). Hence the importance of supporting students in participating in scientific discourses that enables them to acquire skills for making valid claims that are supported by evidence. In this study, a claim is defined as an assertion, conclusion or simply a response to a question (Gotwals & Songer, 2009; McNeill & Krajcik, 2006). Additionally, evidence is defined as observations or data that supports the claim and the evidence could come from scientific data, students' experiments or reading material (Gotwals & Songer, 2009; McNeill & Krajcik, 2006).

There have been considerable efforts to support students' learning about making scientific explanations through curricula and pedagogical supports that scaffold science learners to make valid claims that are supported by appropriate evidence (e.g. Davis, 2003; Davis & Linn, 2004; McNeill & Krajcik, 2006; McNeill & Krajcik, 2009). Some of the supports include scaffolding prompts embedded in curricula units (e.g., Davis, 2003). Scaffolding supports in the form of prompts have been shown to enhance students' making of coherent scientific explanations as measured by their posttest performances (e.g. Davis, 2004; McNeill & Krajcik, 2009). However, as pointed out by McNeill (2006) not much work has been documented on how students use the curricula scaffolds; rather a lot of research has been done on the effects of different types and levels of scaffolds on students' achievement outcomes as measured by the pretest to posttest gains (e.g. Davis, 2003; McNeill & Krajcik 2009). Little is known about how students respond to (or use) the scaffolding support prompts (e.g., see McNeill & Krajcik, 2006). This dissertation study explored students' use of on-line scaffolding support prompts. I was interested on the scientific accuracy of the students' explanations to the scaffolding support prompts embedded in the unit in addition to how they utilized the scaffolding prompts.

Scaffolding may be broadly defined as a process by which a more conversant person like a teacher, adult or peer provides support that enables students to be successful in working through activities that would otherwise be too difficult for them to complete without help (Quintana, Reiser, Davis, Krajcik, Fretz, Golan, Kyza, Edelson, & Soloway, 2004). The notion of scaffolding builds on Vygotsky's concept of the Zone of Proximal Development (ZPD). Vygotsky (1978) defined ZPD as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). As pointed out by Quintana et al. (2004), scaffolding may help students to achieve their learning goals within their ZPD. Students in this study interacted with curriculum unit that had scaffolding support prompts embedded so as to enable students make scientific explanations in their responses. In this dissertation I explored seventh grade students' responses to scaffolding support prompts that were embedded in a heredity Web Based Inquiry Science Environment (WISE) unit called "From Genotype to Phenotype". This dissertation study is a portion of a larger project designed to explore how upper-elementary and early middle school students develop coherent understandings of the concepts of heredity over three years and across successive grade levels (Williams et al., 2010). Consequently, the design principles and science content of the “From Genotype to Phenotype” WISE unit was in accordance to the goals of the larger project.

WISE is an inquiry learning environment that is framed around Scaffolded Knowledge Integration (SKI) framework which is based on the premises of trying to make science accessible to learners, enabling learners to make their thinking visible, providing learners with social support, and providing skills for lifelong learning (Linn & Hsi, 2000). Scaffolded Knowledge Integration (SKI) is an instructional design model that views learners as adding ideas to their repertoire and reorganizing their knowledge (Linn & Hsi, 2000). WISE is a technology platform that was designed to enable learners to go through the knowledge integration (KI) process as they build on their prior knowledge (Linn, 2006; Linn, Davis & Bell, 2004). These authors define knowledge integration as a process of synthesizing multiple knowledge representations into a common model as students are involved in science inquiry.

Inquiry is an approach to learning found in most recent science instructional environments that focus on having students develop a deep understanding of science and discourage memorization of science concepts (Krajcik, Blumenfeld, Marx & Soloway, 2000; Wu & Hsieh, 2006). Krajcik et al. (2000) broadly view inquiry as referring to diverse ways in which scientists study the natural world and make explanations based on evidence. Scientific inquiry practices include hypothesizing, asking questions, designing experiments, recoding and analyzing data and providing scientific explanations (McNeill & Krajcik, 2006). This view of scientific inquiry aligns with WISE in the sense that it is an on-line inquiry environment that provides students with an inquiry platform.

However, despite the importance of involving students in scientific inquiry and discourses such as making scientific explanations, some researchers have reported on the impression that is believed to be widely held by many that science is an abstract and difficult discipline (e.g., Osborne, 2003; White & Frederiksen, 1998). Furthermore, science is reported to be only accessible to a subsection of society that is capable of complex reasoning processes (e.g., White & Frederiksen, 1998). Accessible here refers to ease in engaging, learning and understanding of science phenomena as students build on their prior knowledge and develop more powerful scientific principles (e.g., Linn, 2000). This view implies that not all science learners can either build on their prior knowledge or develop robust scientific understanding as they learn science. In addition, many scientists and science education researchers theorize that meaningful science learning occurs when students build on that prior knowledge as they engage in science inquiry processes (Jenkins, 2006; Kali, 2006; Linn, 2000; Reiss, 2000; Sjǿberg & Schreiner 2005). In sum, building on prior knowledge as students create new knowledge webs is pivotal in science inquiry and knowledge integration processes.

However, not much is known about how students integrate their knowledge by responding to curricula scaffolding support prompts as they learn how to provide scientific explanations (e.g., McNeill & Krajcik, 2006). It is important to map how students build on their prior knowledge as they interact with school science (Fisher & Moody). Additionally, it is essential to explore whether students draw their evidence from their out-of-school or curricula unit to support their claims to the embedded scaffolding support prompts. In my view, identifying some sources of students' evidence may be a key step towards characterizing how students build on their prior knowledge as they form new knowledge webs. In this dissertation study, as I explored seventh grade students' responses to scaffolding support prompts that were embedded in the WISE unit; I was also made attempts to identify some of the students' possible source of explanations. WISE platform enables students' knowledge integration within and inquiry environment as they build on their prior knowledge.

Guided by the Scaffolded Knowledge Integrations (SKI) framework, the "From Genotype to Phenotype" WISE unit was designed to enable students to experience scientific inquiry practices as they learn about genetic inheritance. SKI (discussed in some detail in Chapter two) is an instructional design model that enables learners to add ideas to their repertoire and reorganizing their ideas as they form new knowledge webs (Linn, Hsi, 2000) As pointed out by Linn and Hsi (2000), knowledge integration (KI) is a process of synthesizing multiple knowledge representations into a common model. As part of the larger study, the WISE heredity module was designed to enable students synthesize multiple ideas about heredity and related concepts.

Lewis and Wood-Robinson (2000) broadly define heredity (or genetic inheritance) as the transfer of genetic material from parents to offspring, including the interpretation of the genotypic and phenotypic characteristics in the offspring. Despite the importance of genetics in areas such as genomics, cloning, genetic modification and biomedical sciences in the modern world, genetic concepts remain challenging to learn both from conceptual and linguistic perspectives, (e.g., Tsui & Treagust, 2007). These views suggest that, not only are genetics concepts abstract, the "genetics language" itself is also highly specialized and presents challenges for students to comprehend.

Furthermore, although genetic inheritance and developmental biology are the core of conceptual biology (Moore, 1993), teaching and learning of these concepts continue to pose challenges in the field of biology education (Banet & Ayuso, 2000; Lewis & Wood-Robinson

2000; Slack & Stewart, 1990). This view implies that the understanding of developmental biology and genetic inheritance is critical in the acquisition of fundamentals of biological sciences. In other words, learners need to understand genetic inheritance concepts for them to conceptualize biology. However, as discussed in more detail later, students continue to have difficulty in understanding the core of conceptual biology (e.g., Banet & Ayuso, 2000).

There is considerable research that highlights problems encountered by students as they learn about heredity (e.g., Banet & Ayuso, 2000; Kargbo, Hobbs, & Erickson, 1980; Lewis & Kattmann; 2004; Venville, Gribble & Donovan, 2005; Williams et al. 2010; Wood-Robinson, 1994). Lewis and Kattmann (2004) argued that there is need for more research on helping students understand complex heredity concepts identified in literature. However, Venville et al. (2005) and Williams et al. (2010) highlighted that there is a considerable body of research on early-elementary and high school students' understanding of heredity. Venville et al. (2005) further indicate that there is a research gap about students' understanding of heredity among students in upper elementary and lower secondary years of schooling. This gap shows the need for more research efforts to explore the learning of heredity concepts especially relating to middle school students. This dissertation study contributes towards research about middle school students' learning about genetic inheritance within WISE, a technology enhanced learning environment. Research shows that, in some cases, technology may enhance students' learning of standards-based science ideas (e.g. Linn, 2000).

Additionally, research in science education has shown that students have considerable misunderstandings about genetic inheritance even after instruction (e.g., Banet & Ayuso, 2000; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994). Although this study did not compare different instructional practices, it his however important to note that examination of literature indicates that traditional instructional practices have very little effect on students' understanding of heredity (Banet & Ayuso, 2000; Mintzes & Wandersee, 1998; Johnson & Stewart, 2002; Smith, 1988; Stewart, 1982). It is in this view that technological supports are being explored to find out how students integrate their knowledge as they lean new concepts in school. Traditional instructional practices include teacher's chalk and talk (Wahyudi & Treagust, 2004) and teacher-centered instruction based on the premise that teaching is imparting information (Samuelowicz & Bains, 1992). In the next subsection, I describe the problem being focused on in this study.

Statement of the Problem

There is a considerable amount of literature that identified students' misconceptions on genetic inheritance (e.g., Banet & Ayuso, 2000; Duncan & Reiser, 2007; Fisher & Moody, 2000; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994). What is lacking is comprehensive literature on how misconceptions (also referred to as students' alternative conceptions) held by students may influence their learning and knowledge integration on genetic inheritance. Little is known about the predictive power (for example Clement, 1982) of the students' alternative conceptions on genetic inheritance on knowledge integration in a learning environment. Predictive power here refers to the extent to which students' alternative conceptions may be used to predict how such conceptions can influence students' learning about scientific ideas. For example, Clement (1982) suggested that students' alternative conceptions may have a predictive power of zero (that is zero-order models) if such ideas can be modified with appropriate instructions. This view implies that there are some students' alternative conceptions that can easily be modified by instructions and others that can be held by students even after instruction. Additionally, there could be some instructional strategies that may not be appropriate in modifying students' conceptions for them to develop coherent scientific understanding.

However, Fisher and Moody (2000) argued that there are some students' preconceptions that can interfere with students' learning and that some learners can hold on to their conceptions even after instruction (e.g., Banet & Ayuso, 2000; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994). In this dissertation study, attempts were made to identify some of the students' conceptions reflected in their responses to the scaffolding support prompts they were embedded in the WISE unit.

It is important to note that there has been considerable research efforts designed to support students' learning about scientific concepts such as genetic inheritance (e.g., Lewis & Wood-Robinson, 2000; Williams et. al., 2010). Supports to students' inquiry processes may include curriculum, instruction and technology (Davis, 2004; Linn, 2000; Linn & Hsi, 2006). However, as highlighted by Linn (2000), not all materials designed to support student learning also support lifelong learning. Studies that can promote lifelong learning and improve science understanding have been described and designed by several authors (e.g., Linn, 1995; 1998; 2000; White & Frederiksen, 1998). SKI is based on the view that science learning is a process of integrating ideas. Students' prior knowledge is included in these ideas, and they link that prior knowledge to new ideas as well as reorganize the ideas as they learn science (Davis & Linn, 2000). Students bring into learning environments varied ideas that can interfere with or enhance the learning of particular science concepts (e.g., Aikenhead & Jegede, 1999; Fisher & Moody, 2000). In this study, some students' ideas about genetic inheritance (presumably from their out-of-school experiences) were identified. This dissertation study made an attempt to explain how students' conceptions may influence their understanding of some genetic inheritance concepts.

Besides students' difficulty in learning heredity concepts from both linguistics and conceptual perspectives (Tsui & Treagust, 2007), research has shown that students have difficulty in constructing scientific explanations (e.g. Bell & Linn, 2000; McNeill & Krajcik, 2006, Sadler, 2004; Sandoval & Reiser, 2004). Students' ability to construct scientific explanations is important in the discourse of science and it frames the goal of science inquiry. As pointed out by McNeill and Krajcik (2006), students' understanding of subject matter may also influence their ability to construct scientific explanations. It can be inferred that students are most likely to find it more challenging to construct heredity explanations given the complexity of the content and the process of constructing scientific explanations. In this study, I explored the students' scientific explanations they provided as they responded to on-line scaffolding support prompts that were embedded in the "From Genotype to Phenotype" unit.

As part of the larger study, two versions of the WISE "From Genotype to Phenotype" units were developed. One version of the curriculum consisted activities that were explicit on the importance of making valid scientific claims that are supported with appropriate evidence. In contrast, the second version of the unit did not explicitly explain to students how they can make claims and support their claims with evidence. However, both versions covered same concepts on genetic inheritance. I compared the scores obtained by students who interacted with the different versions using a Knowledge Integration (KI) rubric described by Linn and His (2000). Additionally, I was interested in identifying some of the students' conceptions as revealed by their responses to the scaffolding support prompts.

Research Questions

As pointed earlier, there is a considerable amount of research that highlighted the effect of different types and levels curricula scaffolds on students learning as measured by the posttest gains (e.g. Davis, 2004; McNeill & Krajcik, 2009). However, not much has been documented about students' use of curricula scaffolds (McNeill & Krajcik, 2006). Therefore the main objective of this study was to explore students' responses to on-line scaffolding support prompts embedded in the WISE seventh grade unit. Students provided responses to the prompts that solicited their understanding about genetic inheritance. Students' responses to scaffolding support prompts were scored using a knowledge integration rubric as described by Linn and His (2000). Samples of students' responses were examined for possible source of their explanations.

Using quantitative methods, I compared the on-line response scores of students who interacted with two versions of the curriculum unit; and also students that were taught by different teachers. Two teachers participated in the study; each had five classes of students. I wanted to gain some knowledge as to whether students who interacted with Version One of the From Genotype to Phenotype curriculum unit provided complete explanations as compared to their peers who had Version Two. Furthermore, I explored whether students in this study also held misconceptions on some aspects of genetic inheritance described in the literature. In addition, students' conceptions about genetic inheritance as reflected in their responses to scaffolding prompts were described. As I examined students' responses, attempts were made to explain how some of the students' conceptions may influence their development of coherent understanding of genetic concepts. Attempts were made to identify some possible sources of students' explanations. For some responses, I explained whether students were using evidence from the unit or their out-of-school funds-of-knowledge to support their claims. The specific research questions were:

1) In what ways do students' on-line responses, as measured by the Knowledge Integration (KI) rubric, vary (or not) by the type of curriculum version the students received?

2) In what ways do students' on-line responses vary as a function of their respective teachers?

3) What are some of the students' conceptions on genetic inheritance and related concepts?

Purpose and Significance of the Study

According to McNeill and Krajcik (2006), although research on curricula scaffolds suggests they enhance students learning as measured by posttest gains; there is no systematic data that shows how students interact with the scaffolding supports. The main purpose of this study was to examine students' responses to the on-line scaffolding support prompts. I explored students' responses whether they varied by the version of the curriculum unit the students received or the teacher they had.

As mentioned earlier, knowledge about genetic inheritance is fundamental in students' understanding of biological sciences (e.g., Moore, 1993). However, some learners continue to have difficulty in understanding genetic inheritance even after instruction (e.g., Banet & Ayuso, 2000; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994). This may be a result of curricula supports or instructional strategies that do not address students' difficulties. In this study, it was envisaged that the on-line scaffolding support prompts in the

"From Genotype to Phenotype" unit would enable students to make their thinking visible as they responded to embedded assessment items. As discussed by Fisher and Moody (2000), though knowing what students bring to learning environments is important and instructional supports that aid in extracting students' ideas are pivotal in mapping their understanding. The Web-Based Inquiry Science Environment (WISE) platform enables students to make their thinking and conceptions explicit as they type notes within the unit. This study examined students' responses to scaffolding prompts within the WISE unit as they made their thinking visible around genetic inheritance concepts.

Furthermore, this study attempted to map what students know and how they integrate their knowledge within WISE. The mapping of students' knowledge may support curriculum development initiatives that could possibly enable the design of appropriate instructional strategies. Students' prior knowledge has consequences of knowledge construction (Fisher & Moody, 2000). Examining students' responses to on-line curricula scaffolding prompts can be another way of mapping students' knowledge integration in a technology rich learning environment. By examining students' responses my findings may contribute towards scholarly discussions in the following areas:

1) Students' interactions with on-line curricula scaffolding support prompts. This study contributes to the discussion on students' utilization of the on-line prompts in relation to the importance of the scaffolding supports in curriculum design and development. Conversely, how students make use of the scaffolding support prompts has a bearing on curriculum design principles that puts so much weight and value on the importance of such scaffolds in student learning. The findings in this study maybe informative to

curriculum developers as they develop materials anticipated to scaffold students' learning as well as providing teachers with adequate supports as they enact such curriculum.

2) Students' conceptions about genetic inheritance and related concepts. In this study, I identified some students' out-of-school funds of knowledge that may influence students' understanding about genetic inheritance. It is in this view that this dissertation study may contribute towards discussion on students' conception about genetic inheritance.

3) Knowledge on how students' conceptions can have predictive power towards students' coherent understanding of certain genetic inheritance. In other words, how some of the students' conceptions may influence their understanding regarding certain scientific ideas on genetic inheritance.

In sum, this study contributes towards the scholarly conversations about three main areas of literature -conversations about scaffolding support prompts, students' conceptions about genetic inheritance and how some of students' conceptions may influence their understanding of scientific concepts.

Study Limitations

As mentioned earlier, this study is part of a larger study. Consequently, the design patterns that included the curriculum module design, allocation of students to different curriculum units and the types of the scaffolding support prompts were consistent with other grade levels as per rationale of the larger project. Therefore, this study had no control over the abovementioned study design principles. The larger project design valued providing social support as a principle of the SKI framework. As a result, most students were working in pairs as they responded to the scaffolding support prompts. Therefore, the students' online responses were attributed to pairs of students and not individuals. Consequently, this dissertation study could not examine the effect of students' characteristics (e.g., race, gender, free or reduced lunch) on their knowledge integration scores as reflected by their responses – a limitation that was compounded by the design principles of the larger study. However, although students were encouraged to discuss their ideas before submitting their response online, there was no guarantee that the students reached a consensus before typing their responses. The other limitation was the under-utilization of the embedded prompts which was the scaffolding tool in this study. There were too many students who did not respond to some items as discussed in more detail in the results chapter.

Definition of Terms

Lemke (1990) pointed out that learning science also means learning the use of specialized conceptual language. He further argued that science learning involves communicating in the language of science as part of membership to the science community. As a result, science learning environments can be characterized by terms that are unique to the science community. In this section, I briefly define some terms that are crucial in this study. These terms are also defined in the main body of this dissertation study.

1. A claim is an assertion, conclusion or simply a response to a question and the evidence to support the claim could come from scientific data, students' experiments or reading material (Gotwals & Songer, 2009; McNeill & Krajcik, 2006; Williams et al., 2010).
2. Evidence refers to either observations or data that supports the claim (Gotwals & Songer, 2009; McNeill & Krajcik, 2006; Williams et al. 2010).

3. Scientific explanation refers to a response to a question and it includes a valid claim that is supported by appropriate evidence (Gotwals & Songer, 2009; McNeill & Krajcik, 2006).
4. Genotype is the genetic makeup of an organism. It is the inheritable information found in cells of living organism and can be passed on from parents to offspring.
5. Phenotype is the outward physical appearance of an organism. For example, the presence of dimples on a person's face.
6. "Third space" (also known as "hybrid space") is a space created by students in learning environment and it merges the first space (discourses encountered out-of-school) and second space (the discourses encountered in school) (Moje, et al., 2004).
7. Trait in this study is simply defined as a feature or characteristic of an organism. Features can be inherited from parents (e.g. eye color) or inherited and influenced by the environment (e.g. weight of an individual) or the trait can be acquired from the environment (e.g. tattoo).
8. Knowledge Integration (KI) is a process of synthesizing multiple knowledge representations into a common model (Linn & Hsi, 2000).
9. Scaffolded Knowledge Integration (SKI) is an instructional design model that views learners as adding ideas to their repertoire and reorganizing their knowledge (Linn, Hsi, 2000).

Author's Relevant Experience

This study is part of a larger study designed to develop coherent understanding of heredity and related concepts to fifth, sixth and seventh graders in a Midwestern state in the

United States of America (Williams et al., 2010). In this study, seventh grade students' on-line responses during year two of the larger study were analyzed. With the help of the larger study's research team, I was involved in the design and development of the curriculum unit, lesson plans and the assessment items. I also provided technical support to the two seventh grade teachers as per need during the classroom runs. The two teachers were always open to my presence in their classrooms.

Prior to this study, I had some experience as departmental research assistant exploring college level students' on-line responses. During these activities, I gained some knowledge on studying and identifying patterns in students' on-line responses. In addition, I had opportunities to present the resultant findings at international conferences. Before I came to the USA, I had six years college level teaching experience in my country of citizenship (Zimbabwe) in the areas of general biological sciences, genetics and zoology. Although I do not have much experience in teaching middle school, my biological science academic background and teaching experiences are likely relevant. These enabled me to adequately examine students' scientific explanations on genetic inheritance and related concepts.

Dissertation Overview

This dissertation study consists of five chapters. Chapter one introduces the problem and the research questions. In this chapter, a brief overview of the conceptual framework is highlighted. Chapter two presents a review of literature and the conceptual framework that guided the curriculum development as well as the analytical framework used to interpret the findings. In chapter two I also present a diagram that depicts how I conceptualize the analytical framework by combining SKI (described by Linn & His, 2000) and "third space" (Moje et. al.,

2004) knowledge integration frameworks. Chapter three outlines the “From Genotype to Phenotype” module that was developed as part of the larger study. This is followed by chapter four that describes the methods of data collection and analysis. In chapter five, I present the findings of this dissertation study as an attempt to answer the research questions presented in chapter 1. This is followed by chapter six where the findings were discussed. In chapter seven, conclusions and recommendations are highlighted.

CHAPTER 2

LITERATURE REVIEW

In order to frame my study, I first discuss what the research literature says about students' understanding of heredity and related science ideas. I then describe the theoretical framework that guided the development of the instructional materials, data analysis and the formulation of questions about students' knowledge integration within a web-based unit.

Duncan and Reiser (2007) pointed out that genetic inheritance can be challenging for students to learn mainly because it involves unseen processes studied at different organizational levels such as proteins, genes, cells, organs, organ systems, individual organisms, populations and communities. The organizational levels are hierarchical and as such elements at lower level are building blocks for higher levels and students may find it challenging to reason across different levels (Duncan & Reiser, 2007). For students to develop coherent understanding of genetics in general and genetic inheritance in particular, they need to understand the interactions at different organizational levels (Duncan & Reiser, 2007). However, research has shown that majority of students have difficulty learning about heredity within each organizational level as well as across different organizational levels (Duncan & Reiser 2007; Duncan, Rogat & Yadern, 2009; Stewart & Van Kirk, 1990). For example, students may have difficulty in comprehending the importance proteins, genes, cells and organs in relation to organ systems and variations in populations. In the next subsections, examples of students' difficulties in learning about genetic inheritance and related concepts are highlighted.

Students Understanding about Genetic Inheritance

Genetics can be broadly defined as the study of genes, heredity, and variation of organisms. Heredity (biological inheritance) involves the passage of genetic information from parents to offspring and the interpretation of that information (Lewis & Wood-Robinson, 2000). There have been advances in genetics research resulting from modern science and technology (e.g., Duncan & Reiser, 2007; Lewis & Wood-Robinson, 2000; Trumbo, 2000; Venville et al., 2005). Research indicates that modern genetics is central to the research on and understanding of contemporary issues in biomedical sciences such as cloning and genomics (Tsui & Treagust, 2007). Despite the importance of genetics in society, several researchers have reported that genetics concepts remain the most challenging concepts to teach and learn, from both linguistic and conceptual view points (Tsui & Treagust, 2007; Stewart, 1982; Venville & Treagust, 1998). Current research efforts are aimed at helping students develop robust conceptual understandings of the mechanisms of heredity (Tsui & Treagust, 2007).

In addition to AAAS (1993; 2001), research in science education has demonstrated the importance of students having an integrated understanding of the reproduction process, cell growth and development in order for them to develop a coherent understanding of heredity (e.g., Lewis, Leach, & Wood-Robinson, 2000; Williams et al., 2010). This view suggests that basic knowledge of reproduction and cells is prerequisite to understanding genetic inheritance.

Furthermore, research on student understanding of heredity and related concepts revealed that many students lack insights into the imperceptible processes that link organisms' genotypes to their phenotypes (Banet & Ayuso, 2000; Kara & Yesilyurt, 2008; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994). Lewis and Kattmann (2004) argued that some students hold perspectives that can interfere with their learning of heredity concepts. Lewis and Kattmann (2004) gave an example where students equate genes to traits and also fail to distinguish between phenotypes and genotypes. Although the relationship between growth, cells, reproduction, genes, chromosomes, and heredity well noted in biological education research, Wood-Robinson, Lewis and Leach, (2005) challenged the field to think about why these concepts are often taught at different points within a school year and even in different years. The "From Genotype to Phenotype" curriculum unit developed as part of the larger study incorporated cells, reproduction, genes, chromosomes and heredity concepts and made the connections between them more explicit. However, students have difficulty in understanding each of these concepts. Next I list what the literature says about students' conceptions on heredity and related concepts.

Table 2.1 below summarizes naïve conceptions on genetic inheritance and related concepts held by many students listed by Berthelsen (1999). In the table, I also explained how my study could contribute to the discussion in the science education field concerning how to address students' naïve conceptions about genetic inheritance and related concepts.

Table 2.1

Some Students' Naïve Concepts about Genetic Inheritance and Related Concepts (adapted from Berthelsen, 1999)

Students' Naïve Concept	Berthelsen (1999)'s Suggested Instructional Strategy	My Study's Contribution
Cells Students have difficulty in distinguishing between cell division, cell enlargement and cell differentiation	Instruction should enable students to make connections between cell division and cell reproduction and tissue functions for organisms	I explored students' online responses to examine if students made connections between cell division, reproduction and growth. I also examined if the

Table 2.1 cont'd

	familiar to students such as plant roots	scaffolding support prompts enabled students to make such connections in their online responses
Heredity Some students believe that boys inherit most of their features from their fathers than their mothers and also that girls inherit more from their mothers that their fathers Some students believe that organisms can adapt to changes in the environments and that such changes can be passed on to offspring Students do not understand the relationship between DNA, genes, alleles and chromosomes	Students need to explore a variety in inherited and acquired traits; use models that show relationship between DNA, genes, chromosomes and alleles	Students' responses on prompts related to these concepts were examined for completeness of the scientific explanations that show the relationship between DNA, genes, chromosomes and cells. My analysis included an examination of students understanding of meiosis and how it results in reproductive cells with half the number of chromosomes and the knowledge that offspring inherit from both parents
Reproduction Majority of students fail to distinguish between sexual and asexual reproduction and most of them believe that sexual reproduction produces a stronger offspring as compared to asexual reproduction Some students do not believe that sexual reproduction occurs in plants	Students should have instruction that enables them to understand the similarities and differences between sexual and asexual reproduction in organisms that include plants.	I also examined students' online responses if the provided complete scientific explanations that showed their understanding of sexual and asexual reproduction in plants and animals.

Through their work, which spanned over two decades, Clough and Wood-Robinson (1985; 1994; 2000) gathered evidence showing that students have non-normative ideas about genetic inheritance. For example, they documented many students have difficulty in understanding the equal contribution of both parents in the formation of the genotype of their offspring (Banet & Ayuso, 2000; Clough & Wood-Robinson’s 1985; Kargbo, Hobbs, & Erickson, 1980; Williams et al. 2010; Wood-Robinson, 1994). In particular, these researchers (e.g., Clough & Wood-Robinson, 2000) found that there was a common belief held by many students that the maternal contribution was greater than the paternal contribution, or even that it was the only contribution inherited by an offspring. A similar finding was noted by Kargbo et al. (1980), that many students are of the opinion that offspring inherit more traits from their mother than their father. These findings showed that many students have difficulty in comprehending the equal contribution of both parents in the genetic composition of progeny. Clough and Wood-Robinson also found that twelve-year-old students believed that same-sex inheritance of characteristics (e.g., mother/daughter or father/son) was somehow common.

Research has also shown that students have difficulty with the related concepts of dominance and recessive, and the distinction between gene and allele (Banet & Ayuso, 2000; Clough & Wood-Robinson, 1980; Collins & Stewart, 1989; Santos & Bizzo, 2005; Slack & Stewart, 1990). Some researchers have argued that students’ struggles with understanding genes, alleles and chromosomes are some of the reasons why some students neither can interpret the concepts of heterozygous and homozygous nor could they comprehend the probability concept associated with genotypic and phenotypic frequencies in offspring (e.g., Banet & Ayuso, 2000; Santos & Bizzo, 2005; Slack & Stewart, 1990).

Students Understanding about Concepts Related to Genetic Inheritance

In their study, Lewis and Wood-Robinson (2000) found that many students do not know the location of chromosomes in cells, or that genetic information is found in all living cells. As explained earlier, difficulties experienced by students as they learn about genetic inheritance may be partially attributed to the idea that the concepts abstract, terms that are not commonly used in everyday life, and that genetics involves multiple organizational levels such as genes, proteins, cells, tissue organs, organisms (Banet & Ayuso, 2000; Duncan and Reiser, 2007; Tsui & Treagust, 2007). Consequently, students may experience difficulty in learning about the concepts at each level in addition to understanding the connections between related ideas. As a result, students' understandings about concepts related to genetic inheritance are discussed.

Cells and Reproduction

Genetic material is located in cells and reproduction enables the passing of genetic information from parents to offspring. Therefore, students' understanding about cells and reproduction may enable them develop coherent understanding about genetic inheritance. However, studies have shown that students lack understanding of the relationship between cells, reproduction and heredity (e.g., Banet & Ayuso, 2000). In their research with 482 students aged between 14 and 16, Lewis and Wood-Robinson (2000) found that a majority of the participants did not understand the process of cell division and how that process is linked to the passage of genetic information. In Lewis and Wood-Robinson's study sample, a sizeable number of students believed that cells only contain the genetic information they need to carry out their function. Lewis and Wood-Robinson (2000) also found out that most students were confused by the processes of cell division and chromosome replication. These authors identified that some students believed that chromosomes are shared and not copied during cell division and that many students had difficulty in understanding the terms related to cell division processes in terms of chromosomes and genetic information. Such terms include 'divide, replicate, copy, share, split, reproduce and multiply (Lewis & Wood-Robinson, 2000). Although Lewis and Wood-Robinson

(2000) reported on students' conceptions and their difficulties in learning about these concepts, they did not mention the possible sources of such ideas or supports that may enable their understanding.

Students' failure to make connections between heredity and reproduction may influence their understanding about genetic material is passed from parent to offspring (Banet & Ayuso, 2000; Kargbo et al., 1980; Williams et al., 2010; Wood-Robinson, 1994). Clough and Wood-Robinson (1985) found out that most students recognized that it was common and normal for differences or variations to exist amongst animals of the same species, but a majority of the students indicated that variation was not the norm for plants. In a related study, Okeke and Wood-Robinson (1980) found that even older students (16- to18-year-olds) did not believe that plants were capable of sexual reproduction. This view raises questions about students' perceptions of the role of both parents' genotypes in determining offspring's genotype and phenotype. Apart from exploring whether students in this study had similar conceptions noted by Wood-Robinson and her colleagues, attempts were made to explain students' thinking that may have influenced their reasoning as they provided responses to the scaffolding support prompts.

In summary, there is extensive relevant literature on students' conceptions about heredity and related concepts. However, there is much more to be learned from science inquiry instructional interventions and research on student learning in and from those interventions. There is also much more to be learned from the careful design of technology enhanced inquiry curricula scaffolding supports and how students benefit from them as they learn how to construct scientific explanations – a core scientific practice. More information is also needed on the possible origins of students' understanding of genetic inheritance. Such information is useful in curriculum development and instructional models designed to enable students develop coherent understanding around genetic inheritance. At the same time, students' out-of-school or prior experiences are pivotal in their acquisition of scientific concepts. Knowledge integration frameworks (discussed in detail later) are poised on the idea that students build on their prior knowledge as they form scientific knowledge webs (Linn, 1995; Linn, Eylon, & Davis, 2004; Williams et al., 2010). Hence the need for curriculum developers to understand the possible origins of students' knowledge so as to have instructional models that challenge and build on students' prior knowledge about genetic inheritance. In the following section, Knowledge Integration (KI) and Scaffolded Knowledge Integration are discussed.

Science Learning as Knowledge Integration

There is extensive literature which indicates that most students develop their own ideas and beliefs about science before instruction (e.g., Aikenhead, & Jegede, 1999; Driver, 1989; Kuhn, 1993; Pfundt & Duit, 1991). Palmer (1998) argued that the way students learn science and make meaning of what they learn depend on the students' existing ideas and beliefs that become modified. Knowledge integration is an example of one of the recent frameworks that recognizes students' prior knowledge. Knowledge integration (KI) is defined as an active process where an individual makes links, connections, comparisons and organizes scientific information as they learn new concepts (Linn, 2000). For example, scaffolding prompts in this study were designed to solicit students' knowledge and enabled students to revisit their responses and critique their science ideas. Research has shown that effective curriculum and instruction enables students to integrate their knowledge as the learner builds on the prior knowledge (e.g., Linn & Hsi, 2000). Linn (2000) pointed out that typical science materials ignore or at times contradicts the students' ideas about science. Knowledge integration science materials enable students to build on their knowledge and encourage learners to apply their ideas to their everyday contexts. This idea of building on prior knowledge is poised on the idea that "if students connect ideas from science class to personally-relevant contexts then they will be poised to revisit these ideas outside of class" (p. 783, Linn, 2000). Issues of personal relevance are key to meaningful engagement with science concepts. Research has shown that engagement and learning is achieved if students believe that what they learn is relevant to their lives (Reiss, 2000; Osborne, 2003; Sjoberg & Schreiner 2005; Jenkins, 2006). Knowledge integration therefore takes into account students' prior knowledge and encourages them to make connections between school science and their out-of-school lives thereby appreciating the personal relevance of science. This view suggests that making science learning personally relevant to the learner may be a strategy to enable knowledge integration.

Scaffolded Knowledge Integration (SKI) – Theory that Shaped the Study and Curriculum Unit Development

As mentioned in chapter one, scaffolding in defined as the process by which a knowledgeable person like a teacher or peer provides assistance that enables students to be successful in working through activities that would otherwise be too difficult (e.g., Quintana, Reiser, Davis, Krajcik, Fretz, Golan, Kyza, Edelson, & Soloway, 2004). In the recent past, technological supports for science teaching and learning have been designed in ways that adopt scaffolding (Quintana et al., 2004). The Scaffolded Knowledge Integration (SKI) was proposed as a result of work done over a period of more than two decades by the partnership between experts that include science educators, natural scientists, technologists and classroom teachers (Linn and Hsi, 2000). SKI views learners as adding ideas to their repertoire and reorganizing their knowledge (Linn, 1995; Linn, Eylon, & Davis, 2004; Williams et al. 2010). Next I highlight the principles of SKI.

In particular, this perspective takes on a socio-cognitive frame, thus positing that learning is influenced by both individual construction of knowledge and social supports such as collaborative learning situations between students and teachers/peers or scientists (Linn et al. 2004; Williams et al. 2010). Students sort out their ideas as a result of instruction, experience, observation, and reflection (Linn & Hsi, 2000).

Principles of SKI

The SKI approach features four principles to promote knowledge integration for learners namely; providing social supports for students, promoting autonomy for lifelong science learning, making thinking visible for students and making science accessible for students.

Providing social supports for students. The first principle of SKI emphasizes that providing students with social supports in a science classroom can promote knowledge integration. Vygotsky (1978) introduces the notion of Zone of Proximal Development (ZPD) which is defined as “the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p. 86). Collaborative learning situations such as discussions and debates can be designed so students offer explanations, interpretations and resolutions supported by a peer or a teacher or a scientist (Brown & Palincsar, 1989; Tharp & Gallimore, 1988; Williams et al. 2010). Such interactions can also provide students with opportunities to sort out their science ideas (Linn & Hsi, 2000). In this study, students were provided with social support as they worked in pairs in addition to teacher support. The responses analyzed in this dissertation were provided by student pairs.

Promoting autonomy and lifelong learning. The second principle of SKI, promoting autonomy and lifelong science learning, involves establishing a rich and comprehensive inquiry process that students can apply to varied problems both in science class and throughout their lives (Linn et al., 2004; Williams et al., 2010). For example, by engaging students in reflecting on their own scientific ideas and on monitoring their own progress in understanding science, as well as engaging them in varied and sustained science project experiences can promote autonomous science learning (Donovan & Bransford, 2005; Linn et al., 2004; White & Frederiksen, 2000; Williams et al., 2010). Donovan and Bransford (2005) indicated that using metacognitive strategies such as asking students to show evidence to support their conclusions can help them become aware of and engaged in their own learning. In this study, autonomy and lifelong learning was encouraged by having students reflect on their learning and revisited their ideas as they responded to the scaffolding support prompts embedded within the curriculum unit – in addition to being prompted to support their claims with evidence.

Making thinking visible. The third principle of the SKI approach, making thinking visible, involves modeling and evaluating how ideas are connected and sorted out to form new knowledge webs (e.g., Gobert & Buckley, 2000; Linn, 1995; Schwarz & White, 2005; White & Frederiksen, 1998; Williams et al., 2010). Linn et al. (2004) describe the following pragmatic pedagogical principles associated with making thinking visible: (a) scaffold students to make their thinking visible, (b) model scientific inquiry, and (c) provide multiple representations. Designers can use prompts such as questions or sentence starters to scaffold students in explaining or justifying their ideas (e.g., Davis, 2004; Scardamalia & Bereiter; 1991; van Zee &

Minstrell, 1997; Williams et al., 2010). In this study, students were provided with opportunities to make their thinking visible as they were guided through the inquiry process in addition to responding to scaffolding support prompts. Their thinking was represented by the responses they provided.

Making science accessible. The fourth principle of the knowledge integration approach emphasizes making science accessible, an idea that resonates with the work of Piaget (Inhelder & Piaget, 1972) and Vygotsky (1978). Science can be made accessible to learners as curriculum designers take into consideration three practical pedagogical principles that follow the making science accessible meta-principle (Kali & Linn, 2004). The three practical pedagogical principles are 1) communicating the diversity of science inquiry, 2) connecting science to personally relevant examples, and 3) scaffolding students activities as they engage in inquiry processes (Kali and Linn, 2004; Linn, 2000, Williams et al., 2010). Making science accessible contributes to knowledge integration by building on what students know (Linn et al., 2004). Encouraging students to investigate personally relevant problems and revisit their science ideas regularly, and build on their scientific ideas as they develop more robust understandings can make science accessible (Linn & Hsi, 2000). For example, projects that emphasize scientific inquiry and draw on personally relevant examples connect to what Vygotsky called spontaneous and instructed concepts (Vygotsky, 1978). Additionally, research indicates that driving questions can be used to anchor students' investigations in personally meaningful and challenging inquiry contexts (e.g., Krajcik et al., 1998). In this dissertation study, science was made accessible by having the 'From Genotype to Phenotype" WISE unit anchored around the driving inquiry question "who is the parent"? The inquiry question is described in more detail in chapter three.

Scaffolding Science Learning with Prompts

Research on scaffolds informed the design of the curriculum materials and activities. Scaffolding is a process by which a knowledgeable person like a teacher or peer provides assistance that enables students to be successful in working through activities that would otherwise be too difficult for them to execute (Bransford et al. 2000; Wood, Bruner & Ross, 1976; Quintana et al. 2004; Williams et al., 2010). Though earlier work on scaffolds (e.g., Wood, Bruner & Ross, 1976) made less connections between scaffolds and Vygotsky's zone of proximal development (ZPD), recent educational research has made more explicit links between the two (e.g., Davis, 2003; Linn, 1995; Linn et al. 2004; Linn & Hsi, 2000). According to Vygotsky (1978), ZPD "is the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." In other words, it is the range of abilities that a person can perform with assistance, but cannot perform without help.

The connection between ZPD and scaffolds is based on the premise that scaffolds can help students learn better within their ZPD. Hogan & Pressley (1997) argue that though scaffolds have been mainly the interaction between teacher and student, such one-on-one scaffolds may not be feasible in large classes. McNeill McNeill, Lizotte, Krajcik and Marx (2006) highlighted that when teachers interact with the whole class, teachers encounter multiple zones of proximal development thereby limiting the possible successes of teacher-students scaffolds or support. Instructional materials with embedded scaffolding supports has been the subject of investigation to possible solve problems of lack of one-on-one support in classrooms (e.g. Quintana et al. 2004).

McNeill et al. (2006) investigated the influence of two types of written scaffolds on student learning. The two types were continuous and fading scaffolds. In the McNeill et al. (2006) study, students were exposed to a curriculum unit with either continuous scaffolds that involved detailed support for every investigation, or fading scaffolds involving support that lessened over time. McNeill and colleagues found that all students made significant gains as measured with the pre- and posttest and that the students who experienced fading scaffolds provided better explanations as they responded to the prompts.

Recently, technological supports for science teaching and learning have been designed in ways that facilitate scaffolding. Scaffolding in the form of prompts enables students to reflect as they build on their prior knowledge, thus creating a coherent account of science content (e.g., Davis 2003). Research designed to promote knowledge integration has helped researchers to design prompts that encourage students to reflect. Davis and Linn (2000) examined whether scaffolding influenced students' knowledge integration with two types of prompts. Activity prompts were meant to facilitate task completion and appeared within an activity itself, whereas self-monitoring prompts appeared before and after an activity and were meant to encourage planning and reflection (Davis & Linn, 2000). Davis and Linn found that self-monitoring prompts help students to demonstrate an integrated understanding of science, whereas activity prompts were less effective in prompting knowledge integration.

Just having scaffolding prompts embedded in instruction material, in my view, may not be a guarantee that students would provide valid claims supported by relevant evidence as students respond to the prompts; rather how students make use of the prompts is pivotal in achieving the intended outcome of helping students construct scientific explanations. As defined earlier, a scientific explanation consists of a valid claim supported by appropriate evidence (e.g.

Gotwals & songer, 2009). Claim refers to an assertion, response or conclusion to a question (McNeill & Krajcik, 2006; Toulmin, 1958; Williams et al., 2010). Research has shown that majority of students have difficulty in constructing scientific explanations or claims supported by relevant evidence (McNeill & Krajcik, 2006). In their research with middle school students McNeill and Krajcik (2006) found out that students who interact with instructional materials that scaffold them into making valid claims and supporting them with appropriate evidence would make better scientific explanations in the posttest as compared to those who are not taught how to support claims with appropriate evidence. McNeill and Krajcik argued that it is important for students to be supported on learning how to construct high-quality scientific explanations as they make their thinking visible.

In sum, previous research has shown that scaffolds can influence students' learning of science. Therefore, this research explores how particular scaffolds such as on-line prompts can support the knowledge integration process around heredity and related concepts. I examine the quality of students' responses to different types of scaffolds. I was interested in exploring students' responses to scaffolding supports and examine if they provided complete scientific explanations. In this study scientific explanation refers to relevant responses supported by appropriate evidence (e.g., Williams et al., 2010). In examining the students' responses, attempts were made to identify whether students drew their explanations from the curriculum unit or from their out-of-school experiences. Next, I highlight the framework that enabled me to discuss the observed patterns of some students' responses.

Analytical Framework

In this section, I discuss the theoretical foundations that helped me to gain some understanding of some patterns observed in students' responses. The students' responses were scored using a Knowledge Integration (KI) rubric framed around the SKI (Linn and Hsi, 2000; Linn, Eylon, & Davis, 2004; Williams et al., 2010). As described in more detail later, SKI views learners as adding ideas to their repertoire and reorganizing their knowledge (Linn, 1995; Linn, Eylon, & Davis, 2004). In particular, this perspective takes on a socio-cognitive frame, thus positing that learning is influenced by both individual construction of knowledge and social supports such as collaborative learning situations between students and teachers/peers or scientists (e.g., Linn et al. 2004; Williams et al. 2010). Students sort out their ideas as a result of instruction, experience, observation, and reflection (Linn & Hsi, 2000).

However, students may find themselves in situations where they integrate different and sometimes competing academic and everyday funds-of-knowledge (Moje, Ciechanowski, Kramer, Ellis, Carrillo, & Collazo, 2004). Moje et al. (2004) refer to knowledge integration and discourses drawn from different sources the construction of "third space" or "hybrid space" that merges the first space (discourses encountered out-of-school) and second space (the discourses encountered in-school). As I analyzed students' responses, I made an attempt to identify whether students explained their responses drawing from their "first space" (out-of-school funds-of-knowledge) or from their "second space" (WISE curriculum unit in this case) or from both spaces. In my view, where students draw their evidence to support their claims is important especially when they have competing ideas. Students are most likely to explain their responses using evidence that they believe to be plausible to them. Fisher and Moody (2000) argued that "students' ideas can be so well established and satisfying to them that they tend to be reluctant to replace them with scientific ideas" (p. 57). Using Moje et al. (2004)'s third space or hybrid theory, the students' on-line responses represent the "third or hybrid space". The qualitative analysis of some of the students' responses enabled me to identify the space from which students were most likely to have drawn their explanations to support their claims from. Consequently, "hybrid theory" may inform whether students drew their explanations to scaffolding support prompts from the "second space", the "From the Genotype to Phenotype" curriculum unit or from their "first space" that is their out-of-school experiences. Therefore this dissertation study also drew from Moje and colleagues' characterization of students' knowledge integration in the "third space" (Moje et al. 2004). It is important to note that unlike the larger study, the "hybrid theory" is used as an analytical lens in this study.

Moje et al. (2004) argued that because science is a highly specialized area with assumptions of what counts as scientific knowledge, the idea of integrating in and out-of-school funds-of-knowledge becomes challenging. Moje and her colleagues call the integration of in and out-of-school funds-of-knowledge the construction of a 'third space'. The 'third space' (also known as the hybrid space) amalgamates the 'first space' (i.e. home, community and peer networks) with the 'second space' which consists of formalized institutions such as the school (Moje et al., 2004). This view suggests that students can create a third/hybrid space using their out-of-school and in-school funds-or-knowledge. In other words, students may merge their out-of-school funds of knowledge with the in-school funds of knowledge as they create new knowledge webs. However, although Moje et al., (2004) clearly articulated and acknowledged the existence of different funds-of-knowledge, they did not elaborate on how the out-of-school funds-of-knowledge can enable or hinder students' development of coherent scientific ideas. In my view, even though the students' out-of-school funds-of-knowledge are important as students create new knowledge webs, just merging the different funds-of-knowledge may not be enough for students to learn and understand complex scientific ideas such as genetic inheritance. Hybridity theory, as described by Moje and her colleagues, acknowledges that students may draw from difference sources and also recognizes the convolutions of examining students' everyday funds-of-knowledge. The hybridity theory may apply to the integration of competing knowledge and discourses (Moje et al. 2004). The hybridity theory can also be used to explain some of the students' misconception about genetic inheritance and challenges faced by students as they learn about genetic inheritance and related concepts.

Some researchers have noted that students draw ideas regarding genetic inheritance from different sources including home, peers, movies, comic books, television drama, science fiction books, advertisements and electronic games (Nelkin & Lindee, 2004; Venville, Gribble & Donovan, 2005). Some of these sources do not portray the genetic information in the same way that it is understood in the scientific world. For example, some electronic games have characters that have DNA and they are also capable of "DNA evolving" thereby elevating the character to higher and more powerful levels (Nelkin & Lindee, 2004; Venville, Gribble & Donovan, 2005). There is not much research and information on how such out-of-school encounters influence the students' learning, knowledge integration or understanding of genetic inheritance. Several authors have argued that students need to create scientifically valid maps to enhance the ideal process of learning and understanding biology through integrating ideas and organize ideas into coherent understanding of the scientific concepts (Venville, Gribble & Donovan, 2005; Wandersee & Fisher, 2000; Wandersee, Fisher & Moody, 2000).

The aforementioned view seems to acknowledge what Moje et al. (2004) calls 'hybridity' (or third space) where students bring in their out-of-school funds of knowledge that they acquire from various sources and merge them with in-school funds of knowledge. Hence the need for researchers, curriculum developers and teachers to gather information about students' out-of-school ideas about science concepts so as to develop strategies that effectively enable students to map, merge and integrate their new biology concepts (Venville, Gribble & Donovan, 2005). In sum, students bring into the school space (what Moje and colleagues calls second space) a variety of ideas about genetic inheritance from their everyday experiences (first space according to Moje and her colleagues) and are faced with challenges of mapping, merging and integrating such funds-of-knowledge as they create a 'third/hybrid space'. In this dissertation study, the hybrid (third) space was represented by the students' on-line responses to the scaffolding support prompts. In my view, for students to develop coherent understanding of genetic inheritance, the integrated knowledge webs in the hybrid space need to conform to what traditionally counts as scientific knowledge.

Knowledge Integration in Hybrid Space Model

The diagram below, figure 2.1, depicts how I conceptualize the kinds of spaces that may be created by students as they build on their prior knowledge as reflected in their responses. This model draws from the SKI framework (Linn & His, 2000) and the hybrid theory (third space) described by Moje et al. (2004). The model bridges both of these frameworks.

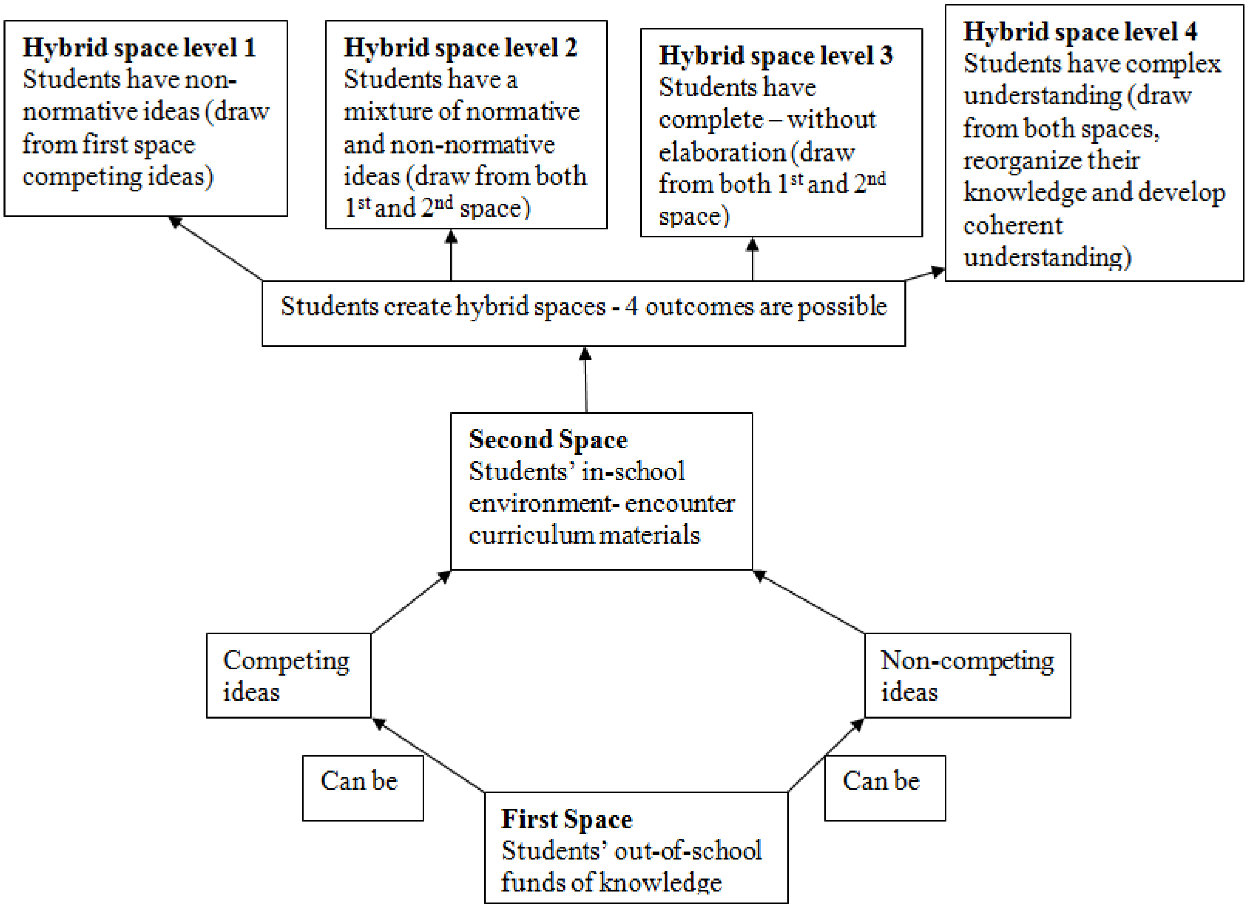


Figure 2.1. Students' Knowledge Integration Conceptual Model

Figure 2.1 illustrates my conceptualization of how students may build on their prior knowledge as they encounter in-school science concepts and form new knowledge webs. The model suggests that students bring into learning environments funds-of-knowledge (gained from their first space) that can be competing or non-competing with academic discourse within the school curriculum materials (WISE unit in this study), their second space. As students interact with the "From Genotype to Phenotype" unit, four outcome scenarios are possible. Though students may create hybrid spaces, such spaces can be in a continuum in as far as students' knowledge integration is concerned. The figure shows the possible hybrid spaces that may be created by the learners as level one thorough level four as shown in the model above. The conceptual model in Figure 2.1 was used to identify whether the students evidence to support their claims was predominantly drawn from the unit or possibly from their out-of-school experiences. The possible hybrid levels are elaborated below.

Hybrid Space level 1. Hybrid space level one maybe a situation where students may fail to develop scientific understanding even after interacting with new scientific concepts they encounter in second space such as the WISE unit. Students in this level could have brought into second space their out-of-school funds-of-knowledge that may interfere with construction of new scientific knowledge webs. In this level students may hold on to their preconceptions from their first space. The preconceptions could be ideas that maybe competing (or even none competing) with the scientific knowledge and students may fail to reconstruct new scientific understanding. In such situations, even after instruction students continue to have non-normative ideas that include misconceptions such as those in table 2.1 above. In my view, students end up in level one hybrid space because of a couple of reasons. For example, the instructional materials and/or strategies may have not challenged students' prior conceptions to enable them to reconstruct their ideas in-order to develop robust scientific understanding.

Hybrid Space level 2. Students at this level may have responses that show a mixture of normative and non-normative ideas. In such cases, students could continue to hold on to some of their preconceptions but mixes them up with information they acquire from the school curriculum materials. In their responses, students at this level may use scientific evidence (encounter in the unit) in addition to the use of their alternative conceptions to support their claims to the scaffolding support prompts. Students in this level most likely scored a two as measured by the knowledge integration rubric described by Linn and Hsi (2000).

Hybrid Space level 3. Student who may be at this level after instruction may be drawing their explanations from second space (WISE unit) but their responses may lack elaboration. In this level, students may also be drawing from both their non-competing first space and their second space but they do not elaborate on their explanation. Students at this level provide near complete responses that lack elaboration and could be in level three as per KI rubric by Linn and Hsi (2000).

Hybrid Space level 4. Students at this level provide responses that show robust understanding of the scientific ideas. This could be a result of students being able to reconstruct their first and second space funds-of-knowledge as they create scientifically robust hybrid spaces.

As I analyze students' responses, I made an attempt to identify whether students were drawing from their out-of-school experience, first space, or they draw largely from the curriculum materials, second space. However, it is important to note the difficulties of determining accurately where students drew their evidence from unless if the explanations clearly demonstrated the possible source of the evidence. Nonetheless, this dissertation study added to the discussion on the kinds of explanations by students as they build on their out-of-school funds of knowledge by integrating such ideas with in-school science ideas.

CHAPTER 3

INSTRUCTIONAL MATERIALS

Introduction

In this chapter, the contents of the instructional materials (“From Genotype to Phenotype” module/unit) are outlined. As discussed earlier, this dissertation study is part of a larger project. Consequently, the “From Genotype to Phenotype” module was developed as part of the larger study. Additionally, the scaffolding support prompts embedded in the unit that formed the basis of my analysis were part of the design principles of the larger study. It is also important to restate here that my study did not evaluate the impact of the curriculum intervention on students’ achievement. Rather, this dissertation study examined students’ responses to the scaffolding support prompts embedded in the seventh grade heredity module, developed as part of the larger study. Therefore the design patterns of the module; the types of questions embedded in the unit together with the assignment of students to different versions of From Genotype to Phenotype were determined by the larger project. Since this dissertation study was not focusing on the effect of the module on students’ achievement or understanding about heredity, only a brief description of the unit is provided as background context on students’ activities.

Module Design Background

Guided by the Scaffolded Knowledge Integrations (SKI) framework, the “From Genotype to Phenotype” WISE curriculum was designed to enable students to experience scientific inquiry practices as they learn about genetic inheritance and related concepts. I participated with other science education researchers to develop two versions of the “From

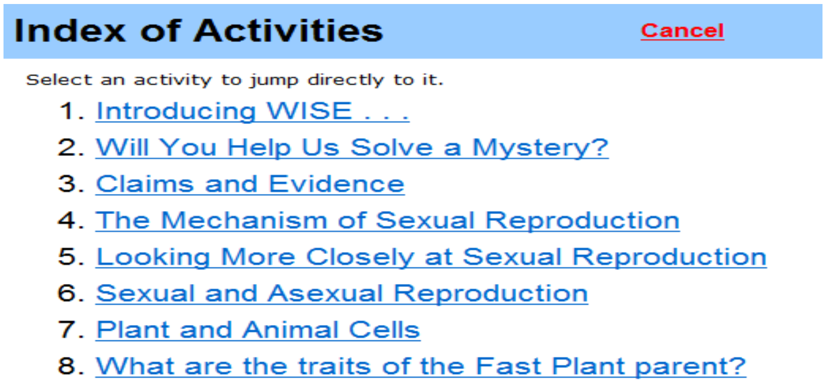
Genotype to Phenotype” curriculum units to support students’ learning about genetic inheritance. One version of the curriculum consisted of an activity that explained the importance of making valid scientific claims that are supported with appropriate evidence. This version was called "Version One" or the "claims/evidence unit". The claims/evidence version of “From Genotype to Phenotype” unit had some scaffolding support prompts that encouraged students to make claims and support their claims with appropriate evidence. In contrast, the second version of the curriculum unit did not explicitly explain to students how they can make claims and support their claims with evidence. This second version was called "Version Two" or "no claims/evidence." However, both versions covered same scientific concepts on genetic inheritance and related concepts. Both units had the scaffolding supports in the form of embedded assessments.

WISE Heredity Instructional Materials

Using the Scaffolded Knowledge Integration framework, a curriculum unit was developed to support inquiry science learning (Linn & Slotta, 2000, Williams et al., 2010) to help students connect science concepts they learn in class to preexisting ideas in order to build on their prior knowledge (Chi, 2000; Linn et al., 2004; National Research Council, 1999; National Research Council, 2005; Palincsar & Brown, 1984; White & Frederiksen, 2000). The WISE instructional materials integrate the internet and feature software tools such as note taking tools, interactive visualizations, embedded assessments, and activities combined in curriculum design patterns to enable students to pursue a line of inquiry (Williams et al. 2010).

The knowledge integration framework has four tenants, namely; making thinking visible, providing social support, making science accessible and enabling lifelong learning. For example, the WISE heredity unit “From Genotype to Phenotype” provided social support in the sense that students worked in pairs as they learned from each other, peers, their teacher and from the curriculum unit itself. The WISE curriculum was also designed in ways that enabled pairs of students to make their thinking visible as they responded to the scaffolding supports embedded in the curriculum unit. In order to make science accessible to students, the WISE curriculum had some scaffolding prompts that were at the beginning and end of some activities to solicit students' prior knowledge and enable them to build on their knowledge as they revisit the prompts at the end of the activity. Science was presumable made accessible because the module was centered on an inquiry question, 'who is the parent?". To encourage lifelong learning, the WISE unit had students practice skills such as making predictions, observing several generations of plants, drawing inferences, analyzing data and reporting findings.

The curriculum materials were designed around target concepts such as cell structure and function, sexual and asexual reproduction as well as biological inheritance (Williams et al., 2010). The index that summaries the activities covered by the students are shown in Figure 3.1. Each activity had at least five evidence steps and a minimum of three embedded scaffolding support prompts, Figure 3.2.



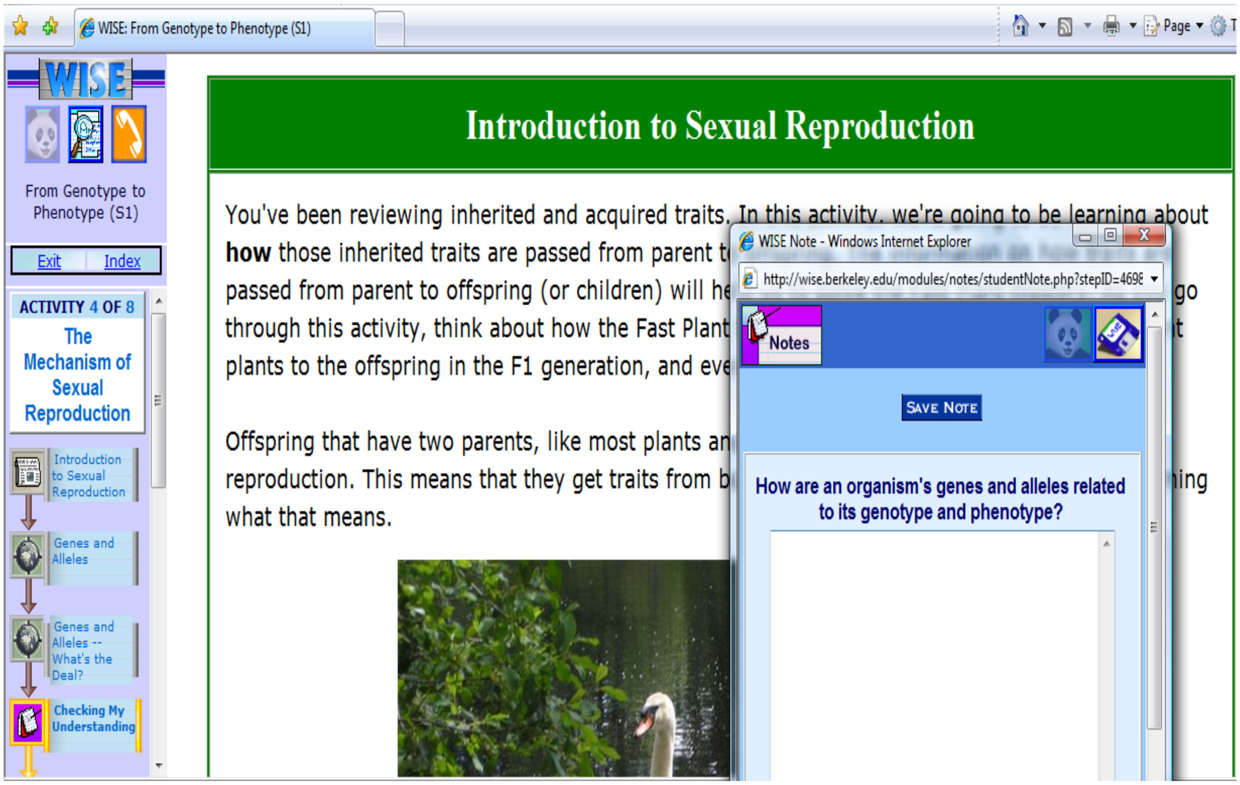
Select an activity to jump directly to it.

1. Introducing WISE . . .
2. Will You Help Us Solve a Mystery?
3. Claims and Evidence
4. The Mechanism of Sexual Reproduction
5. Looking More Closely at Sexual Reproduction
6. Sexual and Asexual Reproduction
7. Plant and Animal Cells
8. What are the traits of the Fast Plant parent?

Figure 3.1. Students' Activities Index Screenshot*

* For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

As shown in the index, the From Genotype to Phenotype module had eight activities. The first activity introduced WISE software features to students. The last activity enabled students to make conclusions about the inquiry question.



Introduction to Sexual Reproduction

You've been reviewing inherited and acquired traits. In this activity, we're going to be learning about
how those inherited traits are passed from parent t
passed from parent to offspring (or children) will he go
through this activity, think about how the Fast Plant t
plants to the offspring in the F1 generation, and eve

Offspring that have two parents, like most plants an
reproduction. This means that they get traits from b ing
what that means.

How are an organism's genes and alleles related to its genotype and phenotype?

Figure 3.2. Screenshot showing an Example of an Activity Inquiry Map

Figure 3.2 shows an example of the inquiry map on the left of the picture. The picture shows four out of eight steps that constituted the activity. The picture also shows the “notes taking” tool which was step four and asking students to provide a response on the relationship between genes, alleles, genotype and phenotype.

Students had a laboratory activity with Fast Plants® where they figured out the genotype of one of the parents using phenotypic ratios of second generation of the plants. It is important to note that the Fast Plants® Mendelian monohybrid inheritance is based on a single gene for stem color. In the Fast Plants® the purple stem is dominant over the green stem. Having sowed the seeds of the second generation of plants, students were to figure out the parental genotypes and phenotypes. The activities were centered on a driving inquiry question for students to solve; “Who is the Parent?” By the end of the unit, students were expected to observe Mendel’s Law of segregation, identify and quantify the phenotypes as well as genotypes that are controlled by a single gene inheritance and use evidence to support claims. At the end of each activity, there were scaffolding prompts that asked students to revisit the inquiry question and make predictions about the phenotype and genotype of the ‘missing’ parent (Williams et al. 2010).

The following is an excerpt that introduced students to the inquiry question:

> We originally planted two Fast Plants in order to do a heredity experiment. These plants were labeled P1 (the first parent) and P2 (the second parent). Once we harvested the seeds from the P1 plant, though, we couldn't remember which plant in our lab was the P2 plant! We planted the seeds from the P1 plant to grow the first generation of offspring plants, F1. We took pollen from some of the F1 plants and put it on some of the other F1 plants in order to pollinate them and produce the seeds to grow another generation of plants, called the F2 generation. Your job is to plant these seeds and grow the F2 plants. The characteristics of these plants, along with the information that we learn from studying heredity, will help us to discover what the missing parent plant looks like, so that we can find it in our lab!

The following is a picture version of the inquiry question. Students observed the second generation from the plants they grew in the laboratory. They then used their observation to figure out the phenotype and genotype of the second parent whose identity was not shown in figure 3.3. For interpretation of the picture in figure 3.3, the reader is referred to the electronic version of this dissertation.

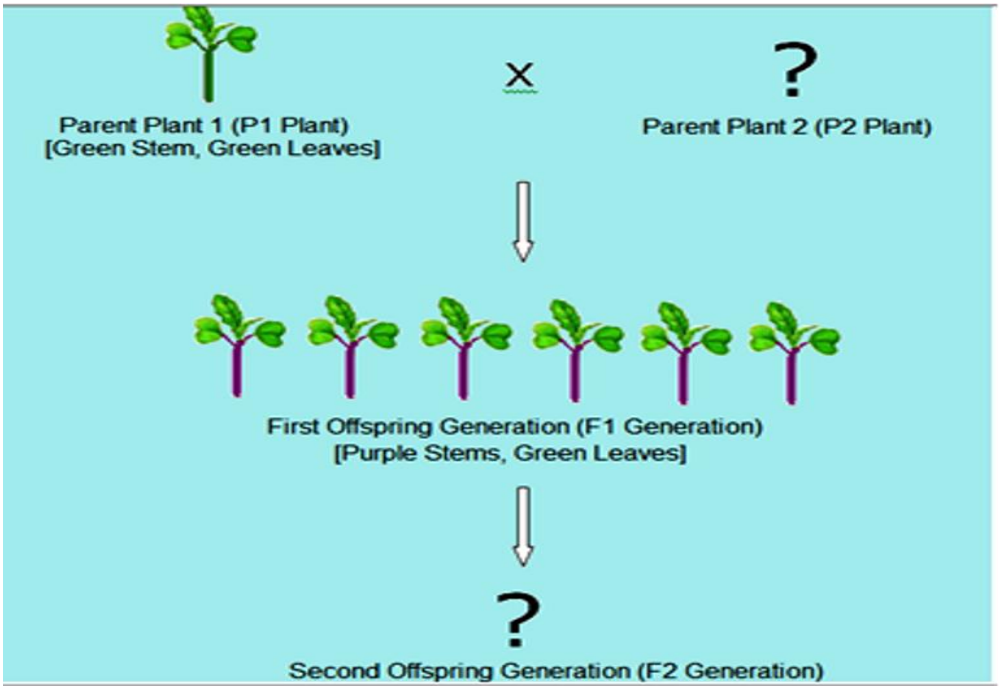


Figure 3.3. The Fast Plant Family Tree

The curriculum was developed by the research team at the university. The research team then met with the participating teachers to go through the curriculum unit and make relevant changes as suggested by the teachers. The research team developed lesson plans that were also modified by the teachers to suit their students' needs. Table 3.1 below shows a summary of the 'From Genotype to Phenotype' WISE curriculum unit covered by the students. An unabridged curriculum outline is in Appendices as table 3.3. Appendices B and C show a complete list of the embedded scaffolding prompts in the order they appeared in the module.

Each activity started with a brief overview of the activity objective. Within each activity there were different steps focusing on specific concepts. In addition, each activity had scaffolding support prompts embedded at different points to enable students to make their thinking visible as they went through the unit. Each activity ended with students responding to scaffolding support prompts on how the content in each activity will help them solve the Fast Plant® mystery and what information they still needed in-order to solve the inquiry question.

Table 3.1

Summary of 'From Genotype to Phenotype' Heredity Unit

Activity	Description
Activity 1 Introducing WISE	Introduces students to the WISE learning environment. Students are shown the features of the learning environment and they also practice taking online notes.
Activity 2 Will you help us solve a mystery?	Introduces students to the curriculum unit and the overarching question for the project. Students are shown a photograph of one parent plant and the first generation of offspring but they are neither told about the genotype of that parent in the photograph nor the phenotype and genotype of the other parent.
Activity 3 Claims and evidence (version 1) Inherited and acquired traits (version 2)	Version 1- Introduces students on making claims and using evidence to support their claims. The activity has steps which solicit students' prior knowledge In this version students analyze what constitutes a valid claim and relevant evidence as they learn about inherited and acquired traits.
	Version 2 - Introduces the idea of "traits" as characteristics of organisms. The activity has steps which solicit students' prior knowledge on traits. Students are asked to distinguish between inherited and acquired traits of plants and animals.
Activity 4 The mechanisms of sexual reproduction	Students learn about sexual reproduction as reproduction involving two parents. Students are introduced to the process of meiosis. In this activity, students are also introduced to Mendel's work. Students use Punnett squares to determine the genotypes of two generations of roses, focusing on flower color
Activity 5 Looking more closely at asexual reproduction	Students learn about sexual reproduction in plants, use of Punnett square to determine genotype and phenotype of an organism.

Table 3.1 cont'd

Activity 6 Sexual and asexual reproduction	Scaffolds students in comparing and contrasting sexual and asexual reproduction, including discussing various advantages and disadvantages of each. Students are introduced to probability as they complete an in-class activity in which they flip a coin to determine the traits that two parents pass on to their offspring which is reproduced sexually; this leads to an in-class discussion of diversity and variety.
Activity 7 Plant and animal cells	Introduces the students to the idea of cells as building blocks and that all living things are made up of cells and cell structure and function. By the end of the activity, students would have learned about cell division, growth, development and specialization.
Activity 8 What are the traits of the Fast Plants parent?	Students determine which Fast Plant trait is dominant and which is recessive, and determine the genotypes of both offspring generations of Fast Plants; finally, students are asked to determine both the phenotype and genotype of the missing parent plant.

The module was covered over a period of six weeks. Each student was given a Fast Plant seed to sow and record the stem color of their plants. Students combined their Fast Plants second generation observations so as to come up with ratios of green stem plants to purple stem plants.

Student's activity with Fast Plants

The primary goal for the curriculum unit activities entailed students to connect their preconceived ideas about reproduction and inherited traits with in-school science ideas (previously described by Williams et al. 2010). Students observed three generations of Wisconsin Fast Plants in the WISE heredity unit to unravel a mystery of parenthood – "What is the second parent's phenotype of the stem color trait?" At the onset of the project, students were shown a photograph of one purple stem parent plant but they were not told that this parent had a dominant expression. Students were also shown the first generation of offspring that all resembled parent one phenotype of purple stem. Students grew the second generation of plants whose phenotypes were green and purple stems. At the same time, this line of inquiry can be a pivotal case for students because they may start to question where the green stem came from. As students observed a second generation of offspring, they had an opportunity to “observe” Mendel’s Law of Segregation.

Scaffolding Support Prompts

As described earlier, the modules had scaffolding support prompts that helped students to make their thinking visible as they responded to the embedded questions. The scaffolds were in the form of embedded on-line prompts. Two versions of the ‘From Genotype to Phenotype’ curriculum units were developed. Both versions covered the same genetic concepts. Version one, claim/evidence scaffolding supports, had an activity that was explicit on what a claim is, how to make a valid claim and support it with appropriate evidence. Claim here refers to an assertion, response or conclusion to a question (McNeill & Krajcik, 2006; Toulmin, 1958). Evidence refers to scientific data, reading materials or students’ experiment findings that can be used to support the claim (McNeill & Krajcik, 2006). Table 3.2 shows examples of some of the embedded online scaffolding supports that prompted students to make a claim and support their claim with evidence. Only a couple of prompts in the claim/evidence version of the unit had sentence starters that prompted students to support their claim with evidence (see Appendix B and C for a complete list of the scaffolding prompts). Students who interacted with the claim/evidence unit were expected to support their claims with evidence even without prompting them to do so. Technically, I expected students who interacted with the claim/evidence version of the unit to give more complete scientific explanations to scaffolding prompts as compared to their peers who had the no claims/evidence curriculum unit.

Table 3.2

Examples of Scaffolding Support Prompts

Activity	Version 1 (Claim/Evidence)	Version 2 (no Claim/Evidence)
Activity 2: Will you help us solve a mystery? (both versions)	What do you think the color of the other parent (P2) in the Fast Plant family tree is? My claim is.... Evidence to support my claim is...	What do you think the color of the other parent (P2) in the Fast Plant family tree is? What do you think the color of the F2 generation will be?
Activity 3: Claims and Evidence (version 1) Inherited and Acquired Traits (version 2)	Living organisms have traits. These traits can be inherited or acquired. Do you know how different people inherit traits from their parents? Use the information you know to answer the following questions What are some traits that you have inherited from your parents? Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.	Living organisms have traits. These traits can be inherited or acquired. Do you know how different people inherit traits from their parents? Use the information you know to answer the following questions What are some traits that you have inherited from your parents? Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

Table 3.2 cont’d

Activity 4: The Mechanism of Sexual Reproduction	Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2; what new claim can you now make? What new evidence do you have to support your new claim? Click on Amanda the Panda for more hints) My claim is…. Evidence to support my claim is… (Please click on Amanda the Panda for hints)	Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2)

Each curriculum unit had 44 embedded scaffolding support questions (see Appendices B & C). The total number of embedded questions includes prompts that were repeated a couple of times such as the one that asked students about what the genotype and phenotype of the other plant as illustrated in the inquiry question. The inquiry question was repeated in each activity so as to give the students an opportunity to reflect on the inquiry based on what they would have learned in each activity. Only five prompts in From Genotype to Phenotype version one explicitly prompted the students to make a claim and support the claim with relevant evidence.

Version one of the WISE curriculum unit had a total of 44 embedded scaffolding support prompts whereas version two had 43 embedded scaffolding prompts. The difference was in activity three. Version one’s activity three supported students to make claims and use evidence as they learned about inherited and acquired traits. Version two’s activity three also focused on inherited and acquired traits but without explicitly scaffolding students to use evidence to support their claims to the embedded prompts. Twenty-seven questions that were common in both versions were scored using a knowledge integration rubric adapted from Linn, Hee, Tinker, Husic and Chiu (2006).

CHAPTER 4

METHODS

Introduction

This study is part of a much larger study designed to explore how upper-elementary and early middle school students develop coherent understandings of the concepts of heredity across successive grade levels, using WISE and offline laboratory investigations (Williams et al., 2010). In WISE, students do most of the activities on the computer using internet-based curriculum materials. The WISE software guides students through content in different activities and steps. The software has discussion tools, notes taking tools and other tools for data visualization, simulations and assessment (Linn & Hsi, 2000; Williams et al., 2010). In this study, students' online responses to different types of scaffolding supports are analyzed. The responses are from seventh grade students within the same school building. The students in this study were taught by two different teachers, Ms. Adams and Dr. Perry. Each teacher had five groups of students. Both teachers implemented the two versions of the six week curriculum unit "From Genotype to Phenotype".

Overview of Methodology

This study relied on both qualitative and quantitative data. The study was qualitative in that I explored emerging patterns in students' responses to on-line scaffolding support prompts. It was partially quantitative because it involved use of a knowledge integration rubric to score the responses and provided quantitative analysis of the scores. Whereas the quantitative analysis aided in internal validation, qualitative analysis provided insights on the meaning of the significance of the findings (Creswell, 2005; Creswell & Clark, 2007). The qualitative data analysis involved examining students’ responses to the on-line scaffolding prompts. As I examined the response, I made an attempt to identify students’ conception and whether they were drawing their evidence to support their claims from their first space (out-of-school) or from their second space (WISE curriculum unit). The main data analysis method was quantitative and the triangulation design (Creswell & Clark, 2007). These methods were used for purposes of converging quantitative data, quality of students’ responses and field observation notes. I used mixed methods approach because it provided for an in-depth understanding of the effects of various levels of scaffolds on students test scores and quality of students’ responses to assessment items as measured by the knowledge integration rubric.

Research Context

This study was carried out in a suburban school district located in the Midwest. As pointed out by Williams et al. (2010), the school district is a socially and economically diverse community. The district has an enrollment of approximately 3,600 students, in four grades K-4 buildings, two grades 5-6 buildings, one middle school (grades 7-8) building, and one high school (grades 9-12) building (Williams et al. 2010). The study was carried out at Pierce Middle School. Pseudonyms are used to protect the identity of the school, students and teachers who participated in the study.

Demographics for Pierce Middle School

The total student enrollment for grades 7-8 was 549 students. As described by Williams et al. (2010) there are about an equal number of male and female students in the school. Twenty seven percent of the students were on free or reduced lunch. The ethnicity for the entire middle school body was 7% Latino, 11% Asian, 28% African American, 57% Caucasian, and 1% Other (Williams et al., 2010).

Participants

My study explored students’ responses to the embedded online scaffolding supports. Using a knowledge integration rubric, I described patterns of students’ responses to online scaffolding supports embedded in two versions of the “From Genotype to Phenotype” curriculum unit. Students were taught by two teachers, Ms. Adams and Dr. Perry. Table 4.1 below shows which class hour had which teacher and version of the curriculum unit. A total of six classes of students interacted with the claim/evidence version of the unit (a total of three class hours per teacher) and a total of four classes interacted with the no claim/evidence type of scaffolding supports. Each class had an average of 25 students, making a total of about 250 students (125 students per teacher). Students were working in pairs as they interacted with the curriculum unit.

Background on Teachers and Teacher Support

Two seventh grade teachers participated in this study. Next, I briefly describe the teachers’ background and support they received as part of the larger study. It is important to note that data analyzed in this study was collected during the second year of implementing the larger project. This means that, the teachers were using WISE for the second time and the students had used WISE when they were in sixth grade.

Ms Adams. As indicated by Williams et al. (2010), Ms. Adams is an experienced African American teacher who was very motivated to implement a Web-based Inquiry Science Environment (WISE) module in her classroom. Prior to implementing the WISE project, “From

Genotype to Phenotype" Ms. Adams had 27 years of classroom teaching experience. During the first professional development meeting prior to implementing the project, Ms Adams indicated that though she was confident in teaching science, she was not at all confident in using computer-based instructional technology. She held a Master's degree in elementary education with an emphasis in English and literacy.

Dr Perry. Dr Perry (as described by Williams et al., 2010) is a highly experienced Caucasian male teacher who had 40 years of teaching experience prior to implementing the WISE heredity project. He holds a PhD in science education. Dr Perry indicated that in college, his major was Biology. He pointed out that he was very confident in teaching science and was somewhat confident with instructional technology.

Teacher support. Two seventh grade teachers participated in this study, Ms Adams and Dr. Perry. The total number of students in this study was approximately 300 (about 150 students per teacher) with a gender ratio of approximately one to one. In this study, students' classes were identified by their hour such as first, second hour, third hour, and so on, up to sixth hour. At the onset of the project, Ms Adams (together with other grades five through seven teacher participants in the district) participated in a three-day, district-wide, summer professional development workshop coordinated by the larger research project team. The topics of the meetings included: (a) discussion of the pedagogy (referring to SKI) associated with the WISE instructional materials; (b) lesson planning; (c) discussion of technical issues related to running the WISE software in classrooms, and (d) discussions of core science content in the WISE curriculum materials. The seventh grade teachers also participated in four after-school meetings during the implementation of the project. The purpose of these meetings was to provide the participating teachers with an opportunity to reflect on their instructional practice regarding students' understanding of the science content. After-school meetings were conducted during the course of implementing the project. These were meant to provide necessary support to the teacher participants and served as debrief meetings where progress and concerns were discussed.

The teachers were provided with the curriculum, including all necessary laboratory materials (e.g., Wisconsin Fast Plants®). Technical assistance was available to the teachers during the enactment of the WISE curriculum unit.

Table 4.1

Curriculum Version Allocation to Class Hours

Curriculum Version	Dr. Perry's class hour	Ms. Adams' class hour
Claim/evidence scaffolding supports (From Genotype to Phenotype Version 1)	1, 5, 6	3, 4, 6
No claim/evidence scaffolding supports (From Genotype to Phenotype Version 2)	2, 4	2, 5

Data Sources and Analysis

The primary data source in this study was students' online responses to embedded scaffolding support prompts. The online scaffolding support prompts were open ended. Students worked in pairs and both could contribute to their online responses. I examined how students who interacted with different versions of the curriculum and taught by different teachers integrated their knowledge around heredity as measured by the KI rubric. I examined their responses for accuracy of claims and use of appropriate evidence as they elaborated on their scientific explanations. The main research question that guided this study is: How do students integrate their knowledge as they interact with the two versions of the 'From Genotype to

Phenotype' curriculum units? My hypothesis was that students who were explicitly taught about making a valid claim and supporting it with appropriate evidence would make more complete scientific explanations in their responses to on-line prompts as compared to those without claim and evidence scaffolding supports. For the purposes of managing data analysis, the broad research question was broken down into sub-questions namely:

1) In what ways do students' on-line responses, as measured by the Knowledge Integration (KI) rubric, vary (or not) by the type of curriculum version the students received?

2) In what ways do students' on-line responses vary as a function of their respective teachers?

3) What are some of the students' conceptions about genetic inheritance and related concepts?

In the next subsection, data sources and analysis done to answer each research question are discussed. Question one and two were combined in the descriptions because they were both analyzed using analysis of co-variance (ANCOVA).

Do students' on-line responses vary (or not) by the type of curriculum version the students received or the teacher they had. Students' responses to the scaffolding support prompts were scored using a Knowledge Integration (KI) rubric. Table 4.2 below shows an example of the KI rubric. The scaffolding prompts chosen for scoring were those that asked for students' conceptual understanding of genetic inheritance and related concepts. Embedded prompts that were not chosen for scoring were self-monitoring prompts that were broad and would not show knowledge integration. For example, at the beginning and end of each activity, there were prompts asking students "What are you looking forward to learn in this activity?" or

"What have you learned in this activity?" Such questions were regarded as being too broad and can warranty any kind of response. There may not be any ideal scientific response or explanation depicting knowledge integration for such scaffolding support prompts.

Table 4.2

Example of the Knowledge Integration Rubric

<table>
<tr><td colspan="4">Question
Is it true or false that boy inherit more traits from their fathers than mother? Please explain your answer
Ideal response
False, offspring inherit half of the genetic material from each parent. Each sex cell has half the number of chromosomes doe to meiosis. Union/joining of sex cells results on an offspring with a full set of chromosomes, half from each parent</td></tr>
<tr><td>Score</td><td>KI Explanation</td><td>Description</td><td>Example of Students work</td></tr>
<tr><td>0</td><td>No answer / off task</td><td>Blank/Didn't make an attempt to answer the question
Repeat the question</td><td>We do not know</td></tr>
<tr><td>1</td><td>Incorrect</td><td>Students writes incorrect response indicating a misconception</td><td>It's True that boys inherit more traits from their fathers more than they do their mothers.</td></tr>
<tr><td>2</td><td>No KI
Students have isolated ideas. Can also be a mixture normative and non-normative.</td><td>Students give a general/vague response</td><td>I think it is false but I do not know why.</td></tr>
<tr><td>3</td><td>Partial KI
Normative ideas without elaboration</td><td>Show knowledge that offspring inherit from both parents but they do not elaborate</td><td>False because boys can inherit from both of their parents not just their dad</td></tr>
<tr><td>4</td><td>Complete KI
Normative ideas with elaboration</td><td>Demonstrate knowledge that offspring inherit half of genetic material from each parent</td><td>False, offspring inherit half of the genetic material from each parent. Each sex cell has half the number of chromosomes doe to meiosis. Union/joining of sex cells results on an offspring with a full set of chromosomes, half from each parent</td></tr>
</table>

A score of zero (0) was given to students who did not make an attempt to respond to the prompt. Students whose response had a misconception were assigned a score of one (1). This enabled me to make a count of students who had a misconception on some genetic concept. Out of a total of twenty seven scaffolding support prompts, seventeen were scored using a zero to four scale, five scored from zero to three and five scored from zero to two. The total possible score for each pair was night three. An example of a prompt that was scored up to two is “what do you already know about asexual reproduction?” The five questions scored of this type were too broad and did not specific. Furthermore, any response could have counted as an acceptable claim because the question asked what the students knew. However, for the example just mentioned, students scored a zero if they left it blank or indicated that they did not know. They scored a one when they indicated a response suggesting they had a misconception – for example, if students said ‘asexual reproduction involves two parents’. Students scored a two when they provided a response that indicated some understanding about asexual reproduction – for example, if students said ‘asexual reproduction involves one parent’.

The students’ scores were entered into Statistical Package for the Social Sciences (SPSS) for analysis. I performed analysis of covariance (ANCOVA) to examine the effect of scaffolding type on students’ total KI scores. The students’ KI scores were used as a dependent variable and teacher and scaffolding support as fixed factors.

What are some of the students’ conceptions about genetic inheritance and related concepts. To answer this question, I explored a sample of students (one class from each teacher) for some of the conceptions identified in literature. Students whose response indicated that they had a misconception scored a one for that item. This enabled me to quantify students who shared the misconception. Apart from giving the response a KI score, I also identified the students’ conceptions and some possible sources of the evidence they used to support their claims. I used the knowledge integration conceptual model as described in chapter two and depicted in Figure 2.1 to characterize students' use of evidence in their responses to the scaffolding support prompts. I wanted to establish whether students were using evidence from the module or from their out-of-school experiences to support their claims. For example, students who stated that they inherited eye color from their father or mother had their responses characterized as having been drawing from their out-of-school experience. This analysis enabled me to identify some of the students' out-of-school experiences that may influence their knowledge integration in a learning environment. In Table 4.3 I summarize the data analysis for each of these research sub-questions.

Table 4.3

Summary of Data Sources and Analysis

Research Question	Data sources and analysis
1) In what ways do students' on-line responses, as measured by the KI rubric, vary (or not) by the type of curriculum version the students received?	Students' online responses were scored using the knowledge integration (KI) rubric. These were entered in Statistical Package for the Social Sciences (SPSS). Each pair of students had 27 scores entered and the total score calculated for each pair. Using SPSS I performed analysis of covariance (ANCOVA) to examine the effect of scaffolding type on students' total KI scores. I had the KI scores as dependent variable and teacher and scaffolding support as fixed factors.
2) In what ways do students' on-line responses vary as a function of their respective teachers?	Students' online responses scored using the knowledge integration (KI) rubric Examining teacher effect – overall how students taught by one teacher compare to students taught by the other teacher – I performed ANCOVA as I did for research question 1. I also split the file by teacher and examined treatment effect for each teacher.

Table 4.3 cont'd

3) What are some of the students' conceptions on genetic inheritance and related concepts?	Patterns of students' responses were explored. To aid my analysis a score of zero reflected that the pair of students did not respond to the prompt and a score of a one reflected those who had some misconceptions especially on items that asked on ideas whose misconceptions were identified in literature. I sampled responses in-order to explore patterns of students' explanations. Using the hybridity (third space) theory as a lens, I examined the students' responses and explained the possible space from which the students drew their explanations or evidence from.

Scoring reliability. In-order to calculate the reliability of my scoring, I had another post graduate student with experience in using KI rubric score some of the students' responses. I calculated the agreement percentage and it was 93%. This suggested that our scoring was in agreement for 93% of the responses and was a good sign that I used the rubric accurately.

CHAPTER 5

RESULTS

Introduction

My data analysis addresses the following specific questions: 1) In what ways do students' on-line responses, as measured by the KI rubric, vary (or not) by the type of curriculum version the students received? 2) In what ways do students' on-line responses vary as a function of their respective teachers? 3) What are some of the students' conceptions on genetic inheritance and related concepts? Students' responses to the embedded scaffolding support prompts were the main data sources used to answer these questions. Additionally, classroom observation notes were used to support some of the trends in students' utilization of the scaffolding prompts. Some of the images in this dissertation are presented in color.

As discussed in Chapter Four (Methods), students in this study were divided into two groups. One group interacted with a WISE curriculum unit that was explicit about making valid claims and supporting them with appropriate evidence. This unit was version one or claims/evidence version. Version two is the no claims/evidence unit. Though the science content was the same in both curriculum units, students interacting with the claim/evidence WISE unit had some scaffolding support prompts in three activities reminding them to make a claim and support it with evidence. This study explored how students responded to the scaffolding support prompts especially with regard to the scientific accuracy (as measured by the KI rubric) of their on-line responses. I was particularly interested in whether students interacting with different versions of the WISE units had different KI scores. Additionally, I sought to understand whether students' responses varied, if at all, by the teacher the students had.

Effect of Different Curriculum Versions on Students' KI Score

In this subsection, findings that answer the following question are presented; in what ways do students' on-line responses, as measured by the KI rubric, vary (or not) by the type of curriculum version the students received? As indicated earlier, two versions of the WISE unit were developed. As part of the instructional model, version one had an activity dedicated to explain what a claim and evidence are and why these elements are important when making scientific explanations. Whereas the science content of the two versions was the same, version two of the curriculum was neither explicit on use of evidence to support claims nor prompted students to support claims with evidence. The knowledge integration (KI) rubric (described by Linn & Hsi, 2004) was used to evaluate the scientific accuracy and completeness of students' responses to the embedded on-line prompts. I also examined if students in this study had some of the misconceptions identified in the literature. Using the hybridity (third space) theory (Moje et al., 2006) attempts were made to identify the space that could be a possible source of students funds-of-knowledge evident in students' responses to some scaffolding support prompts embedded in both units. In other words, were students drawing their evidence from the project (or school) to make and support their claims?

I examined whether there was a significant difference in students' total scores (as measured by the KI rubric) between those who interacted with the different versions of the WISE curriculum unit. First I look at the overall effect of different versions then analyze by teacher to examine the scores by scaffolding type within each teacher. In other words, I examined 1) if students who interacted with version one had better KI scores than students who interacted with version two of the WISE curriculum across the two teachers, 2) within each teacher, was there a difference in KI scores between students who interacted with version one as compared to version two of the WISE unit.

As described earlier, the WISE program is designed in such a way that students are provided with social support as they work in pairs. The majority of the students in this study were working in pairs as they interacted with the units. However, a couple of students in some classes were not paired because either their teacher chose not to pair them or the class had an odd number of students. Ideally, each pair discussed their ideas before typing and submitting their responses on-line. Although the pairing of students was part of the design of the knowledge integration framework that values social support, it made it impossible to explore the influence of other student variables (e.g. gender and socio-economic status) on KI scores. Therefore the analysis in this study was limited to group variables such as the version of the curriculum and the teacher the students had.

It was possible that the outcome to my research questions could have been influenced by the version of the curriculum the students received. First I examined the effect of different versions of the WISE unit on students' KI scores. This was clearly an important baseline analysis because the outcome determined my further analysis. For example, significant findings would determine whether grouping students by the type of curriculum was necessary in subsequent analysis.

Analysis of covariance (ANCOVA) was used to examine the overall differences between scores obtained by students who interacted with the different versions of the unit. Overall here refers to the total number of students from both teachers combined. ANCOVA analysis suggests that there was no significant difference in students' scores as measured by the KI rubric between students who interacted with the claim/evidence curriculum unit and those who interacted with the no claim/evidence version of the WISE curriculum *F*(1, 141) = 3.35, *p* = 0.07. Previous research (e.g. McNeill et al. 2006) reported that students who interacted with claim/evidence curriculum provided significantly better explanations on the posttest as compared to the control group.

Unlike McNeill et al. (2006)'s research focus, this dissertation study examined students' responses to curriculum scaffolds and not their pre and posttest responses. In other words, this study did not examine the effect of the WISE module on students' performance as measured by the pre-posttest gains. Rather, I examined the students' responses to the scaffolding support prompts. However, the findings in this study were contrary to my expectations. I expected that students who interacted with the claims/evidence version of WISE would have better responses and higher KI scores as compared to the students who interacted with the no claims/evidence version as measured by the KI rubric. Since there was no significant differences in students' KI scores based on the type of scaffoldings supports, students' examples shown in this study were selected without considering the version of the unit the students interacted with.

The findings from this dissertation study imply that both versions of the WISE unit were equally valuable. The students' KI scores did not depend on the version of the WISE unit the students used. However, I was also interested in examining if students taught by one teacher had KI scores that were influenced by the version of the unit the students had. I separated the students' KI scores by their teacher and version of the curriculum the students received. Unpredictably, I found that Ms Adams' students who interacted with the no claims/evidence version of the WISE unit had higher KI scores as compared to the students who interacted with the claims/evidence version of the curriculum, *F* (1, 71) = 5.42, *p*= 0.023. This was a surprising finding as I expected the opposite. However, it is possible that the differences just mentioned may be explained by the differences in the manner the students utilized the scaffolding prompts. These differences are explored and explained further when I discuss teacher effect later in this chapter. However, Dr. Perry's students showed no significant differences between those who interacted with claim/evidence group and the no claims/evidence group F (1, 70) = 0.165, p= 0.69. Although I highlighted the differences in some detail in a later section, it is important to note that Dr. Perry's students' mean KI scores were lower than Ms. Adams' students (see for example the Figures 5.1 and 5.2 below).

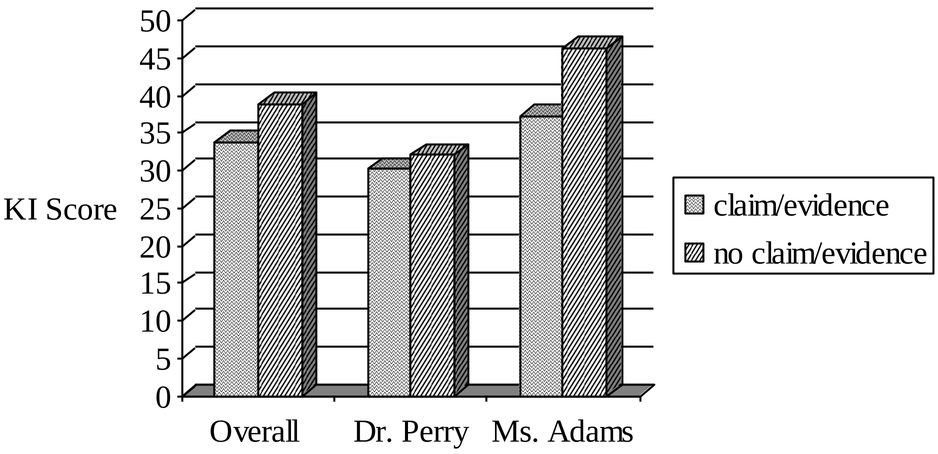


Figure 5.1. Students' KI Mean Scores For Each Scaffolding Support Type

As shown in Figure 5.1 above, overall, students who interacted with the no claim/evidence unit had a slightly higher mean score as compared to the mean score of students who interacted with the claim/evidence version. However, the difference was not statistically significant, $F(1, 141) = 3.35$, $p = 0.07$. In addition, compared to Dr. Perry's classes where difference was not significant, the difference was significant in Ms. Adams' students. Overall refers to the total number of students from both teachers combined. Later in this chapter, I highlighted some of the observations that may account for these differences in students' KI scores.

Figure 5.2 below shows the KI scores within each curriculum version compared between the two teachers and overall. In both versions, Ms. Adams' students had higher means. The details of these differences are discussed in a later section.

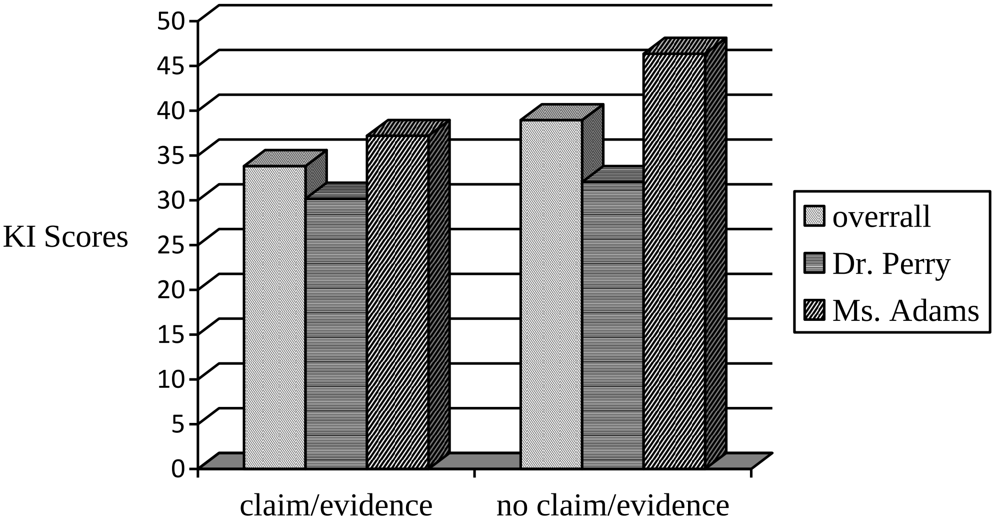


Figure 5.2. Students' Mean KI Score for Each Curriculum Unit

As shown in figure 5.2, Ms. Adams' students had higher means than Dr. Perry's students. Next, some of the evidence that may account for the differences just described is presented.

Relationship between Teacher and Students' KI Scores

In this subsection, I was interested in the question "was there a significant difference in mean KI scores between students taught by Ms Adams and those taught by Dr. Perry?" The relationship between teacher and students' scores as measured by the KI rubric was examined. The focus was on exploring whether students' KI scores were dependent on which teacher the students had. Analysis using ANCOVA suggests that there was a significant difference in raw mean scores between students taught by the two teachers $F(1, 141) = 12.51$, $p = 0.001$. Ms. Adams' students had a significantly higher raw score average (i.e. 41.76) than Dr. Perry's students (i.e. 31.11). It is important to note here that the possible total raw score was 93. The total score of Ms. Adams' students ranged from a minimum of 6 to a maximum of 65. Dr. Perry's students' scores ranged from a minimum of 1 to a maximum of 72.

Analysis of the students' responses to the on-line scaffolding support prompts suggests that the differences just mentioned could have been largely because of the differences in how the on-line curricula scaffolding prompts were utilized rather than differences in students' conceptual understanding. To support this claim, in the next section I highlighted some of the differences in use of scaffolding prompts by students taught by the two teachers. Two pieces of evidence were identified that could possibly support the claim that the observed differences in mean scores could be attributed to differences in the manner in which scaffolding prompts were used by the students taught by the two teachers.

First there was a difference in the manner in which students utilized the scaffolding supports. By utilization I mean the extent to which the students made use of the prompts by responding or not responding to the embedded scaffolding supports. The second piece of evidence pertains to the ways the teachers themselves guided their students through the WISE curriculum units. It is important to note that these two pieces of evidence are not mutually exclusive. For example, a teacher may guide students and encourage them to respond to the scaffolding support prompts embedded in the WISE curriculum module, or the teacher may leave it up to the students to respond or skip some prompts. Consequently, students' utilization of the scaffolding prompts maybe a partly indication or reflection of the teacher's instructional practices, guidance or supports they provide to their students. Next I highlight the observations made on patterns of students' use of scaffolding support prompts that may explain possible reasons why the means were significantly different between students taught by different teachers. Students' utilization of the scaffolding support prompts are described next.

Students' Utilization of Scaffolding Support Prompts

The WISE unit was designed in such a way that a few of scaffolding support prompts were embedded at the beginning and at the end of an activity. The rationale was twofold. First, prompts were repeated so as to elicit students' conceptual understanding of specific concepts before and after interacting with an activity. The second rationale was to offer students an opportunity to revise their claims and evidence as they interacted with the curriculum unit. It was envisaged that students would gather more knowledge as they interacted with the WISE unit and thereby develop better understanding of the genetic concepts.

However, as in more detail in later sections, students were likely to skip a scaffolding support prompts that appeared more than once in the WISE curriculum. Guided by the KI rubric, a score of zero was awarded to students who did not attempt to respond to particular scaffolding prompt. However, only a handful of students in Dr. Perry's group attempted to respond to repeated questions. This finding (none response to scaffolding support prompts) has implications in curriculum development where scaffolding support prompts are a major aspect of the curriculum design. It was evident that most students did not utilize prompts that gave them the opportunity to revisit their claims based on evidence they presumably acquire as they continue to interact with the curriculum unit. For example, item number two asked students if boys inherited more traits from their fathers than their mothers. Literature suggests that a majority of students hold the misconceptions that boys inherit more from their fathers than their mother and also that girls inherit more from their mothers than their father (e.g., Berthelsen, 1999). The prompt (number two mentioned above) appeared twice at the beginning of activity 2 and end of activity 2. In Ms Adams' class, 16% of her students did not respond to the pre-activity prompts as compared to 81% who did not respond to the post-activity. A similar trend was observed with Dr. Perry's students where 18% did not respond to the pre-activity and 58% did not attempt to respond to the identical post-activity item. Despite the fact that a sizeable number (e.g. Table 5.4 shows 26% overall; 28.8% Ms Adams; 23.6% Dr. Perry) had shown in their pre-activity response that they believed boys inherited more from their fathers than their mothers, the majority of students did not revisit their earlier claims by way of responding to the post-activity.

Although it is not clear why students did not respond to the repeated items, the fact that they did not respond to such scaffolding prompts maybe an indication that they identified repeated prompts and chose not to respond to them for the second time. For example, a couple of students indicated that they had already responded to a similar prompt. It can be inferred that those who did not respond to the post-activity prompts could have been holding on to their earlier claims and therefore did not realize the need of restating their claims. Alternatively, it is possible that the students did not realize the importance of responding to items that appeared to be duplicates. However, there were two pairs of students' pairs who did not respond to any of the scaffolding support prompts.

There were instances where the whole class in Ms Adams' class did not respond to a scaffolding support prompt. Having the whole class (whose teacher was observed to often go through the unit step by step with her students) skip a scaffolding support prompt was an indicator that the students were not prompted to respond to the item. For example, all students in Ms Adams’ hours 4, 5 and 6 did not respond to item 7. Item 7 asked students ‘how are organism’s genes and alleles related to its genotype and phenotype?’ Students in hours 2 and 3 in Ms Adams’ group who responded to item 7 had similar responses and majority of them scored a three out of a possible score of four. A score of a three was a reflection of students’ understanding of the concepts as measured by the KI rubric. Such inconsistencies in the manner the participants utilized the scaffolding support prompts might partially explain why Ms Adams’ students had a significantly higher mean than the students taught by Dr. Perry. Next I describe some of the observed instructional practices that may help to explain some of the differences in students’ KI scores.

Some Insights into the Teachers' Instructional Practices

A note about what is and what is not included in this dissertation study. This dissertation study is not about teacher’s instructional practices. The focus of this dissertation study was to explore students’ on-line responses to scaffolding support prompts embedded in the WISE unit that was designed to enhance students’ learning about genetic inheritance. The main question of this study is: "How do students who interact with a claim/evidence version of the WISE curriculum provide explanations to the scaffolding support prompts as compared to those who interact with the no claim/evidence version?" In the students’ explanations, the robustness and patterns of the responses were examined using a KI rubric. Attempts were made to explore whether students were using evidence from the WISE units or their out-of-school experiences to support their claims as per model presented in chapter two. Therefore this study does not attempt to make causal claims about the relationship between teacher instructional practice and students' learning. Rather, I focus on explaining patterns observed in students responses that may be a result of the teachers’ scaffolding practices. However, this study acknowledges that the approach taken by the teachers in guiding their students through the unit may have influenced the manner in which students utilized the scaffolding support prompts embedded in the curriculum unit.

In my view, the teachers’ approach or guidance on the utilization of scaffolding supports is critical especially on the enactment of a unit that puts an emphasis on the importance of such prompts. In this study therefore, attempts were made to describe in qualitative terms some of the observations that can partially account for why Ms. Adams’ students had significantly higher Knowledge Integration (KI) mean scores and similar responses to some of the scaffolding support prompts.

Patterns in students’ use of scaffolding support prompts

As I explored students’ responses to the web-based scaffolding support prompts, I identified some differences in the manner in which students taught by different teachers used the scaffolding support prompts. In my view the differences in the manner in which learners use the scaffolding support prompts could be suggestive of the idea that the two teachers in this study had different approaches in guiding their students through the WISE unit. Teacher scaffolds may have influenced the way in which students in this study utilized the embedded scaffolding support prompts.

During the enactment of the WISE unit, the two teachers were provided with various types of professional development supports. Teacher support included classroom visits intended to provide the teachers with technical supports such as helping students register with the WISE program. During the enactment of the WISE unit, I visited both teachers on a daily basis for six weeks to provide support as per need. Though there was no rubric to record the teachers' instructional practices, at the end of each class visit I made summative notes on how the teachers guided their students through the unit. Members of the larger project also visited the two teachers and we collaborated the notes taken during classroom support visits.

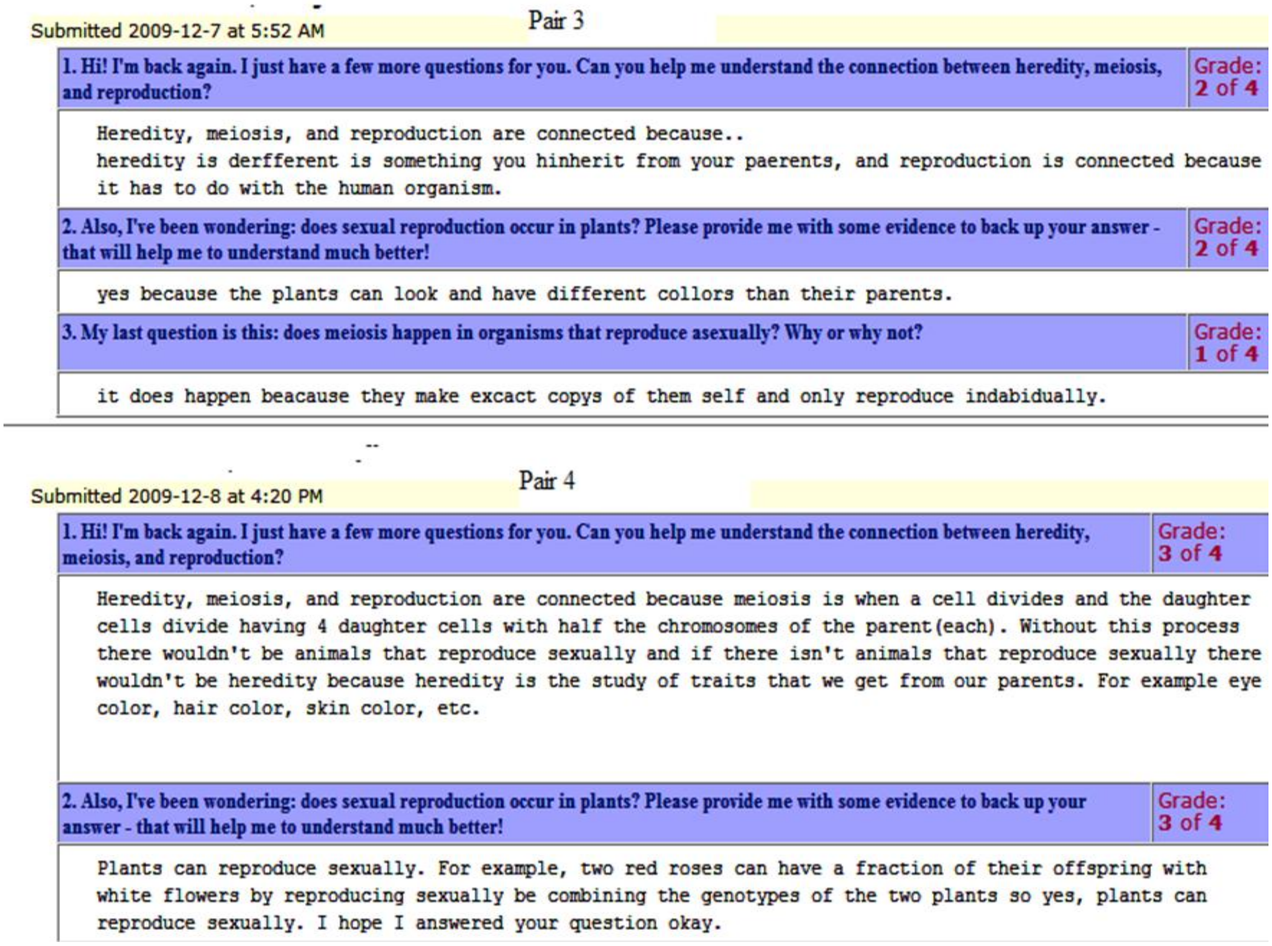
From my classroom observations, I noticed that Ms Adams and Dr. Perry's instructional practices or ways they guided their students through the WISE unit were different. I will start by describing observations made on Dr. Perry's approach and provide evidence from his students' on-line responses that support the observed practices.

Dr. Perry's instructional supports. Typically, Dr. Perry would give his students the agenda of the day that included the WISE activities he expected each pair of students to complete. He would also make a list of vocabulary words he wanted his students to pay special attention to as they went through the day's activities. Dr. Perry occasionally encouraged his students to respond to the scaffolding support prompts embedded in the unit. Other than that, Dr. Perry would let the students go through the unit at their own pace while going by his daily agenda. It was common for Dr. Perry's students in the same classroom to be at different points in the WISE curriculum unit. For example, figure 5.3 below is a picture that shows how students in Dr. Perry's students utilized the scaffolding prompts. The picture shows students' responses to an on-line scaffolding support prompts. The WISE program records the date and time that each pair submitted a response. The program also arranges students' responses in alphabetical order of the students per each class. An example of Dr. Perry's students using he WISE unit at their own pace is described below when students completed Activity six, ‘Sexual and Asexual Reproduction’.

Embedded in Activity Six, Step six, was a note with three scaffolding support prompts. These scaffolding prompts in Step Six were:

1. Hi! I’m back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction?
   Heredity, meiosis, and reproduction are connected because...
2. Also, I’ve been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer – that will help me to understand much better!
3. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not?

Although these items appeared labeled 1 through 3 in the WISE unit, they were items 17 through 19 in my list of items analyzed in this study. This is mainly because the WISE program numbers items in each step as a separate entity. The prompts were designed to elicit students' understanding of the relationship between heredity, meiosis and reproduction, whether plants sexually reproduce and reason that meiosis is involved in reproducing sex cells in sexually reproducing organisms. These questions were embedded after students had interacted with activities that presumably would have enabled them to produce complete scientific explanations. It can be seen in the picture below (Figure 5.3) that student pairs 3 and 4 in Dr. Perry’s first hour submitted their responses on different dates and times. Pairs 3 and 4 were in Dr. Perry's first hour class. Although students’ were in the same class hour, pair 3 submitted their response to items 17 through 19 on December 7, and pair 4 submitted on December 8. This clearly testifies to the observation that Dr. Perry’s students did not go through the unit at the same time. The early times of response submission in the pictures are because the WISE server is hosted at the University of California, Berkeley, which is three hours behind the Eastern Time zone. The classroom observations coupled with the time of submission of Dr Perry’s students’ responses clearly show how Dr. Perry’s students in the same class would be at different points in the WISE curriculum unit. In sum, students in Dr. Perry's class proceeded independently through the unit at different paces, and with minimal teacher scaffolds.



Pair 3

Submitted 2009-12-7 at 5:52 AM

1. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Grade: 2 of 4

```
Heredity, meiosis, and reproduction are connected because..
heredity is derfferent is something you hinherit from your paerents, and reproduction is connected because
it has to do with the human organism.
```

2. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better! Grade: 2 of 4

```
yes because the plants can look and have different collors than their parents.
```

3. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not? Grade: 1 of 4

```
it does happen beacause they make excact copys of them self and only reproduce indabidually.
```

Pair 4

Submitted 2009-12-8 at 4:20 PM

1. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Grade: 3 of 4

```
Heredity, meiosis, and reproduction are connected because meiosis is when a cell divides and the daughter
cells divide having 4 daughter cells with half the chromosomes of the parent(each). Without this process
there wouldn't be animals that reproduce sexually and if there isn't animals that reproduce sexually there
wouldn't be heredity because heredity is the study of traits that we get from our parents. For example eye
color, hair color, skin color, etc.
```

2. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better! Grade: 3 of 4

```
Plants can reproduce sexually. For example, two red roses can have a fraction of their offspring with
white flowers by reproducing sexually be combining the genotypes of the two plants so yes, plants can
reproduce sexually. I hope I answered your question okay.
```

Figure 5.3. Example of Dr. Perry’s Students’ Utilization of Scaffolding Prompts

Table 5.1 below depicts Dr. Perry’s class responses to scaffolding supports depicted in figure 5.3 above. The responses in table 5.1 show how Dr. Perry’s students had different responses and that was an indication that pairs of students may have completed their work independently of the teacher and other pairs.

Table 5.1

Dr. Perry's First Hour Responses Demonstrating Utilization of Prompts

Item 17. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? *Ideal Response.* Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis is a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are	Item 18. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer – that will help me to understand much better! *Ideal response.* Sexual reproduction also occurs in plant. For example, some plants have flowers with male and female parts. The transfer of pollen grains from anther to stigma is called pollination and leads to union of	Item 19. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not? *Ideal response.* Meiosis does not occur in asexually reproducing organisms. Meiosis is a process of cell division that results in production of sex cells that have half the amount of genetic material. Asexually reproducing organisms do not produce sex	

Table 5.1 cont'd

connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring	male and female cells.	cells so there is no meiosis in such organisms	
Students' responses to item 17	*Students' responses to item 18*	*Students' responses to item 19*	*Comment*
Pair 1P1 Heredity, meiosis, and reproduction are connected because… heredity is deferent is something you inherit from your parents, and reproduction is connected because it has to do with the human organism. (2)	Yes, because the plants can look and have different colors than their parents. (2)	It does happen because they make exact copies of them self and only reproduce individually. (1)	These responses show lack of understanding of heredity, meiosis and reproduction. They did not understand the functions of meiosis and that it occurs only in sexually reproducing organisms. Though the pair made a correct claim that some plants can sexually reproduce, the explanation was not elaborated
Pair 1P2 Heredity, meiosis, and reproduction are connected because meiosis is when a cell divides and the daughter cells divide having 4 daughter cells with half the chromosomes of the parent (each). Without this process there wouldn't be animals that reproduce sexually and if there isn't animals that reproduce sexually there wouldn't be heredity because	Plants can reproduce sexually. For example, two red roses can have a fraction of their offspring with white flowers by reproducing sexually be combining the genotypes of the two plants so yes, plants can reproduce sexually. I hope I answered your question okay. (3)	No, it doesn't because in an organism that reproduces asexually doesn't need this process because they don't have sperm cell or egg cells and finally because only one parent is needed so there is no need for the cells to have half the chromosomes. (4)	This pair shows conceptual understanding on the relationship between heredity, meiosis and reproduction; they know that sexual reproduction occurs in plants though the example given was not fully explained.

Table 5.1 cont'd

heredity is the study of traits that we get from our parents. For example eye color, hair color, skin color, etc. (3)			
Pair 1P3 Blank	Blank	Blank	This pair did not respond to all three items
Pair 1P4 Blank	Blank	Blank	No responses to the three items
Pair 1P5 Blank	Blank	Blank	No responses to the three items
Pair 1P6 Heredity, meiosis, and reproduction are connected because heredity is how genes are passed from parent to offspring. Reproduction is when one or two parents have sex to reproduce or split one of their cells to reproduce to make an off spring. (2)	Yes, they do. The sperm cells are the pollen carried to plant to plant with bees, and the eggs are inside the flower. (3)	Yes, meiosis does happen in animals that reproduce asexually. They do so, so they can make cells that are different, instead of all the animals being the exact same. (1)	This pair believes that meiosis occurs in asexually reproducing organisms. Maybe this was because they could not articulate the connection between meiosis and reproduction
Pair 1P7 Blank	Blank	Blank	No responses to the three items
Pair 1P8 Heredity, meiosis, and reproduction are connected because... Heredity is the study of genes and things like meiosis and reproduction. (1)	Yes, because the grain of pollen is the sperm which finds its way to the ovum or egg of the female. (3)	Yes, because meiosis is when they reproduce by dividing which is asexually. (1)	Though this pair understands that some plants can sexually reproduce, their response show lack of understanding of meiosis and how it relates to sexual reproduction

Table 5.1 cont'd

Pair 1P9 Heredity, meiosis, and reproduction are connected because...Heredity is the things you inherit from your parents! Reproduction and meiosis are the systems and ways to make offspring. (2)	Yes it does!!!! They have special "anal holes" in which sperm moves through. (2)	Yes. Because they can have different traits, and still be "the same" in looks and things. (1)	This pair does lack coherent understanding of the functions of meiosis in organisms and how that is related to reproduction
Pair 1P10 Heredity, meiosis, and reproduction are connected because... meiosis and reproduction (0)	Blank (0)	Blank (0)	This pair did not provide responses
Pair 1P11 They are all a part of reproduction (2)	Yes. When the pollen of another plant come in contact with the plants ovum, it makes seeds. This is why all plants do not look alike. (3)	A form of it, binary fission happens. (1)	The pair indicates that plants can sexually reproduce but they do not give a convincing explanation. They did not show coherent understanding of heredity, meiosis and reproduction
Pair 1P12 Heredity, meiosis, and reproduction are connected because... Heredity is the study of reproduction and meiosis. (1)	Yes it does. Plant babies get traits from both parents. A parent with a green stem and green leaves and a parent with a purple stem and purple leaves have a baby with a purple stem and green leaves. They both had a part in it (2)	Meiosis has to do with DNA. Meiosis is the reproduction of cells. To reproduce you need to have meiosis cells from each parent. (1)	On item 18, the pair is drawing from the WISE unit when they give an example of stem color they did with their Fast Plants. Other than that, students lack understanding of the concepts asked about meiosis and reproduction
Pair 1P13 Blank	Blank	Blank	No responses to the three items

Table 5.1 cont'd

Pair 1P14 Heredity, meiosis, and reproduction are connected because... they all require dividing or result in producing new offspring. (2)	Yes, because in flowers, bees transfer nectar from one flower to the next, which fertilizes or pollinates it. (3)	No, because the organism doesn't have sex cells to divide. (3)	This pair provided responses that show understanding of sexual reproduction in plants though they did not articulate the relationship between heredity, meiosis and reproduction
Pair 1P15 Blank	Blank	Blank	No responses to the three items

Based on the responses shown in the Table 5.1 above, a majority of the students did not show understanding of the relationship between meiosis and reproduction. Failure to articulate this relationship may be a reflection on students' difficulty in understanding the functions of meiosis in organism. The failure to understand the relationship may partially explain why the same students who had difficulty in articulating the relationship did not show understanding that meiosis does not occur in asexual reproduction. This may suggest that students who do not comprehend the functions of meiosis in living organisms are most likely to have difficulty in distinguishing variations that result from sexual reproduction as compared to asexual reproduction. Students' failure to explain the relationship between meiosis and reproduction may also partially explain their difficulty in understanding how the mechanisms of genetic inheritance occur from both parents.

It is important to note that Dr. Perry's students provided responses that suggested each student pair's effort in generating responses to the scaffolding support prompts. A different pattern was observed with Ms Adams' students. Based on my summative observations, Ms Adams' instructional practice was somewhat different from Dr. Perry's.

Ms. Adams' instructional supports. Unlike Dr. Perry, Ms Adams had the whole class go through the unit at the same pace and ask them to read aloud different sections of activities. During the first two activities, she gave her students time to respond to the scaffolding support prompts. From Activity Three on, Ms Adams discussed the responses to the scaffolding support prompts with the whole class. She would summarize the ideal response and then gave students the opportunity to type and submit their responses. As a result, most of her students ended up having very similar responses to the scaffolding supports and thus, they had the same KI scores for most items. I observed that most of the time, Ms. Adams guided her students through the unit step by step. Her students rarely opened steps with scaffolding supports without being prompted to do so by their teacher. This likely explains why some of her classes skipped some prompts. This may explain why some of her classes skipped some prompts. Figure 5.4 below shows examples of how students in Ms. Adams' classes used the WISE unit. Table 5.2 below shows the rest of the students' responses whose examples are in figure 5.4.

Pair 1

Submitted 2010-2-17 at 7:38 AM

1. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Grade: 3 of 4

Heredity, meiosis, and reproduction are connected because...meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction.

2. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better! Grade: 3 of 4

Yes, pollen is the term used for "sperm" in plants. When the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction in plants.

3. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not? Grade: 3 of 4

No, MEIOSIS ONLY TAKES PLACE IN ORGANISMS THAT REPRODUCE SEXUALLY. MEIOSIS REFERS TO "SEX CELLS ONLY"

Pair 2

Submitted 2010-2-17 at 7:38 AM

1. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Grade: 3 of 4

Heredity, meiosis, and reproduction are connected because meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction.

2. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better! Grade: 3 of 4

Yes, pollen is the term used for "sperm" in plants. WHen the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction.

3. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not? Grade: 3 of 4

no, misosis only takes place in organism that reproduce sexualy. meiosis refers to "sex cells only"

Figure 5.4. Example of Ms Adams' Students' Utilization of Scaffolding Prompts

Figure 5.4 above shows that apart from pair 1 and pair 2 submitting their responses on the same date (2/17/2010) they submitted the responses at the same time, 7:38am California time. Of particular note is the similarity of the students' responses to the scaffolding prompts. Consequently, all the students had the same Knowledge Integration (KI) scores. It is in this view that I argue that the teachers' instructional practices may have somewhat influenced students' KI scores. Hence, teacher scaffolds could be used to explain some of the differences in students' KI scores observed in this study.

Table 5.2

Ms Adams' Third Hour Responses Demonstrating Utilization of Prompts

Item 17	Item 18	Item 19
Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Ideal Response Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring	Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer – that will help me to understand much better! Ideal response Sexual reproduction also occurs in plant. For example, some plants have flowers with male and female parts. The transfer of pollen grains from anther to stigma is called pollination and leads to union of male and female cells.	My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not? Ideal response Meiosis does not occur in asexually reproducing organisms. Meiosis is a process of cell division that results in production of sex cells that have half the amount of genetic material. Asexually reproducing organisms do not produce sex cells so there is no meiosis in such organisms
Students' responses	*Students' responses*	*Students' responses*

Table 5.2 cont'd

Pair 3A1 Heredity, meiosis, and reproduction are connected because meiosis refers to sex cells. Sex cell hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction. (3)	Yes, pollen is the term used for "sperm" in plants. When the pollen units with the egg in the ovary a seed is produced. This is sexual reproduction in plants. (3)	No, meiosis only takes place in organisms that reproduce sexually. Meiosis refers to "sex cells only" (3)
Pair 3A2 Heredity, meiosis, and reproduction are connected because...meiosis refers to sex cells. Sex cell holds (2)	Blank	Blank
Pair 3A3 Heredity, meiosis, and reproduction are connected because...meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction. (3)	Yes, pollen is the term used for "sperm" in plants. When the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction in plants. (3)	No, meiosis only takes place in organisms that reproduce sexually. Meiosis refers to 'sex cells only' (3)
Pair 3A4 Heredity, meiosis, and reproduction are connected because meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction. (3)	Yes, pollen is the term used for "sperm" in plants. When the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction. (3)	No, meiosis only takes place in organism that reproduce sexually. Meiosis refers to "sex cells only" (3)
Pair 3A5 Heredity, meiosis, and reproduction are connected because... meiosis refers to sex	Yes, pollen is a term used for "sperm" in plants. When pollen unites with the egg in the ovary a seed	No, meiosis only takes place in organisms that reproduce sexual. Meiosis refers to " sex cells only" (3)

Table 5.2 cont'd

cells. Sex cells hold hereditary materials that allow a variety of traits to be passed to offspring during sexual reproduction. (3)	is produced. This is sexual reproduction in plants. (3)	
Pair 3A6 Blank	Blank	Blank
Pair 3A7 Heredity, meiosis, and reproduction are connected because...Meiosis refers to sex cells. When sex cell hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproductions. (3)	Yes, pollen is the term used for "sperm" in plants. When the polled unites with the egg in the ovary a seed is produced. This is sexual reproduction in plants. (3)	No, Meiosis only takes place in organisms that reproduce sexually. Meiosis refers to "sex cell only." (3)
Pair 3A8 Blank	Blank	Blank
Pair 3A9 Heredity, meiosis, and reproduction are connected because meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction. (3)	Yes, pollen is the term used for "sperm" in plants. When the pollen unties with the egg in the ovary a seed is produced. This is sexual reproduction in plants. (3)	No, because meiosis only takes place in organisms that reproduce sexually. Meiosis refers to "sex cells only." (3)
Pair 3A10 Heredity, meiosis, and reproduction are connected because...when sex cells unite or join together. (2)	Yes. Pollen is the term used for sperm for a plant (2)	No, meiosis only takes place asexually. (2)

Table 5.2 cont'd

Pair 3A11 Heredity, meiosis, and reproduction are connected because...meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring during sexual reproduction. (3)	Yes. Pollen is the term used for sperm in plants. When the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction in plants (3)	No it doesn't. Meiosis only takes place in organisms that reproduce sexually. Meiosis refers to sex cells only. (3)
Pair 3A12 Heredity, meiosis, and reproduction are connected because... Meiosis refers to sex cells. Sex cells hold hereditary material that allows a variety of traits to be passed to offspring. (3)	Yes, pollen is the plant term used for sperm in plants, when the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction. (3)	Blank
Pair 3A13 Heredity, meiosis, and reproduction are connected because...meiosis refers to sex cell hold hereditary material that allows a variety of traits to be passed to offspring during sexual production (3)	Yes. Pollen is the term used for "sperm" in plants. When the pollen unites with the egg in the ovary a seed is produced. This is sexual reproduction in plants. (3)	No, it does not. Meiosis only takes place in organisms that reproduce sexually. Meiosis refers to sex cells only. (3)

I did not provide specific comments for the responses shown in table 5.2 above. This was because the students provided similar responses, and as such it was not possible to tease out what the students understood and what they did not. It is clear from the responses that the teacher was providing scaffolds by making sure that her students responded and as per her suggested answers. If this is indeed what happened, this practice would have undermined the rationale of embedded scaffolding support prompts. Prompts were embedded to help students to reflect on their thinking and understanding as they went through the unit. Additionally, WISE platform is an inquiry learning environment which encourages independent student response to prompts. However, this was not the case with Ms. Adams who provided step by step guidance to her students. The next subsection highlights some students' conceptions as reflected in their responses to the on-line scaffolding support prompts.

Students' Conceptions about Genetic Inheritance

This subsection addresses the question- what are some of the students' conceptions about genetic inheritance and related concepts? In this study, a scientifically complete response was measured using the KI rubric as described by Linn et al. (2006). The KI rubric enabled me to examine whether students were providing scientifically valid claims as they interacted with the WISE units. In this section, I examined students' responses to scaffolding prompts that were designed to solicit students ideas on heredity concepts previously reported to be challenging for a majority of learners. Research (e.g. Lewis & Wood-Robinson 2000) has shown that some students believe that boys inherit more of their features from their fathers than they do from their mothers. Similarly, some students believe that girls inherit more features from their mothers than they do from their fathers. However, not much research has documented possible sources of such misconceptions or how some of the students' alternative conceptions may hinder knowledge integration in learning environments. For example, little is known about how the belief by some students, that boys inherit more traits from their fathers than they do from their mothers influences their comprehension and knowledge integration on biological inheritance and related concepts. Furthermore, there is not much literature on suggested instructional models that may enable students (with such beliefs) recreate their hybrid space knowledge webs. As described in

Chapter two, a hybrid or third space is a space created by students as they fuse their out-of-school and in-school funds of knowledge (Moje, et al., 2004). As pointed out by McNeil and Krajcik (2006), there is not much work that documented students' utilization or responses to curricula scaffolds. In my view, students' responses to curricula scaffolds (such as the on-line scaffolding prompts) may reflect students' thinking in their hybrid spaces as they build their new knowledge by fusing different funds of knowledge. In sum, not much is known about the predictive power of students' alternative conceptions on genetic inheritance and its implications on teaching and learning in different environments.

Embedded in the curriculum units were items that solicited students' knowledge on some documented misconceptions held by students around heredity concepts. At this juncture, it is important to note that the embedded on-line scaffolding support prompts were intended to enable students to reflect on their thinking and revise their ideas as they interacted with the unit. Unlike other forms of assessments where students do not have opportunities to refer to texts during testing, students in this study were free to refer to the text in the WISE unit as they responded to the embedded scaffolding prompts. In such situations, one expects students to draw their claims and evidence from the WISE unit or to refer back to the text in the unit in cases where they were in doubt. Nonetheless, students did not have to refer to text in the unit if they felt confident that they were making scientifically valid claims and supporting their claims with what they thought was the most appropriate evidence. Unless stated, majority of the scaffolding support prompts examples described in this dissertation appeared after the students had already interacted with the activities covering the science concepts that would enable them to respond to the items. A couple of prompts were embedded before and after the activity to examine whether students changed their conceptual understanding as a result of interacting with the "From Genotype to Phenotype" curriculum unit. Next I highlight some students' conceptions to some items that were embedded in the unit.

Passing Genetic Material from Parents to Offspring

Some students fail to distinguish between inherited and acquired traits and some (incorrectly) believe that acquired traits can be passed on from parents to offspring (e.g. Clough and Wood-Robinson, 1985; Kargbo et. al., 1980). Research has shown that a sizeable number of students believe that a gene is the same as trait (Lewis & Kattmann, 2004). Based on such students' conceptions, the scaffolding support prompts solicited students knowledge on misconceptions listed in literature. There were items designed to determine whether students could identify and list inherited traits. Items 1 to 3 were at the beginning of an activity on 'inherited and acquired traits'. The same items appeared at the end of the same activity (as item 4 to 6 respectively). The items were:

1. What are some traits that you have inherited from your parents?
2. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.
3. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

For the aforementioned scaffolding support prompts, I was not only looking at scientific accuracy of students' explanations to scaffolding supports using the KI rubric, but also make an attempt to identify some of the possible sources of their explanations. Moje et al. (2004) has argued that different funds-of-knowledge shape students' oral and written explanations. Using hybridity theory that recognizes the complexity of examining students' literacies as a lens, Moje et al. (2004) pointed out that students draw their knowledge and explanations of their world view from a variety of sources that include home, school and peers. Moje et al.'s argument is in agreement with literature on genetics which suggests that students draw competing and non-competing ideas regarding genetic inheritance from different sources including their home, peers, movies, comic books, television drama, science fiction books, and electronic games (e.g. Nelkin & Lindee, 2004; Venville, Gribble & Donovan, 2005). In this study I examined students' responses and tried to identify whether students were drawing their explanations to the embedded prompts from the curriculum or from their out-of-school experiences. For example, in their explanations were students using examples in the curriculum unit or other sources. I do acknowledge the complexity of accurately identifying a possible source of students' explanations unless the response is suggestive of a clear source. The quantitative analysis I reported earlier suggests that there was no significant difference in students' responses as measured by the KI rubric between students who interacted with different versions of the WISE unit. Consequently, selection of examples of students' response was not based on the type of scaffolding support the students had.

Item 1. Item 1 was embedded before and after (as item 4) an activity on inherited and acquired traits. Item 1 (and 4) asked students to list some traits they inherited from their parents. The item did not require an explanation. Guided by the KI rubric, students scored a zero (0) if they did not respond to the question and scored a one (1) when they had misconceptions such as listing an acquired trait (see Table 5.3 below). Apart from listing traits, there was no explanation required so this was not a knowledge integration question. Additionally, item one was not specific on the number of heritable features the students should list. Consequently, the maximum possible score was a three for listing at least two inherited traits. This decision was taken because the question did not specify the number of traits the students should list. Furthermore, the question asked students about “traits” and not a “trait”. This meant that the question required students to list more than one trait. Hence my rationale for awarding full score to students who mentioned any two inherited. Table 5.3 below (this Chapter) is the rubric for item one (and four).

Table 5.3

Item 1and 4 Rubric

Rubric for Question 1 (and 4) What are some traits that you have inherited from your parents? Ideal response eye color, skin color, natural hair color and texture, freckles, dimples, PTC (Phenylthiocarbamide) tasting etc.			
Score	KI explanation	Description	Example of student work
0	No answer / Blank	Blank	
1	Not correct/misconception	Students list acquired traits	“Pierced ears”
2	No KI Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	List both inherited and acquired traits or one inherited trait	“tattoo and eye color” or “height” or “freckles”
3	Full KI Makes scientifically valid claims	List at least two inherited traits	Eye color, hair color, skin color etc.

Table 5.4, below, depicts the frequencies and percentages of students’ KI scores for item 1 before and item 4 after the activity. It is important to note here that 15.2 % of the students did not respond to scaffolding prompt item 1 as compared to 68.3% on item 4. Descriptive statistics also show that 15.1% of Ms. Adams’ students did not respond to the pre-activity item 1 as compared to 80.1% who skipped the post activity item 4. For Dr. Perry’s students, 16.7% did not

respond to pre-activity item 1 and 56.9% did not respond to item 4. The rationale of repeating some scaffolding support prompts was to enable students to revisit their earlier claims. The fact that some students did not respond to repeated prompts suggests that they did not have a chance to reflect on their earlier claims and thereby undermining the curriculum design principles of repeating scaffolding support prompts.

Table 5.4

KI Score Frequencies for Item 1 and 4

Item 1 (and 4). What are some traits that you have inherited from your parents?						
KI Score	Item 1. Pre-activity Frequency	Item 4. Post-activity Frequency	Item 1. Pre-activity %	Item 4. Post-activity %	Item 1. Pre-activity Cumulative %	Item 4. Post-activity cumulative %
0	22	99	15.2	68.3	15.3	68.8
1	7	2	4.8	1.4	20.1	70.1
2	30	10	20.7	6.9	41.0	77.1
3	85	33	58.6	22.8	100.0	100.0

Items 1and 4 asked students to state the features they inherited from their parents. As stated earlier in this chapter, listing at least two inherited traits was sufficient to score maximum possible points as per KI rubric. However, apart from listing the features, some students attributed each listed trait to a specific parent. I did not give a score for the explanations provided by students because it was not asked for by the question. Nevertheless, it is important to note that some students were identifying the parent from which they thought they inherited a certain feature. For example students would say ‘nose shape from my mother’ or ‘eye color from my father’. Although the explanations were noted, there was no score rewarded for the explanation. To examine the patterns of students’ responses, I randomly selected a class from one teacher and then picked a corresponding hour from the other teacher. I wanted to explore whether students taught by different teachers had similar pattern of responses.

Table 5.5

Examples of Students’ Responses to Item 1and 4 (Ms. Adams’ Second Hour)

Item 1 What are some traits that you have inherited from your parents? Ideal response Eye color, skin color, natural hair color and texture, freckles, dimples, PTC (Phenylthiocarbamide) tasting		
Students’ Responses		
Pre-activity responses (score)	Post-activity responses	Comment
Pair 2A1 My partner has black hair from her dad, and brown from her mom. She has really dark brown eyes like both her parents. I have hair from my mom and blue eyes from my mom (3)	Blank (0)	These students are attributing inheritable features to a specific parent. In their response, there is mention of at least 2 heritable traits. They were using their out-of-school funds-of-knowledge (the parent they look like) to explain their claims.
Pair 2A2 I have inherited my brown eyes from my mom and my partner inherited athletic abilities from parents. (2)	Blank (0)	This pair had a mixture of normative and non-normative ideas. Their response indicates a belief that athletic abilities can be genetically passed on from parents to offspring. In addition, they were using their out-of-school funds-of-knowledge to explain their claims.

Table 5.5 cont'd

Pair 2A3 My hair looks like my dad, and my eye color like my mom. I have eyes like my dad. (3)	Blank (0)	This response shows how students attribute certain trait to a parent. This pair used their out-of-school funds-of-knowledge (the parent they look like) to explain their claims.
Pair 2A4 My eye color and my hair color are two traits I have inherited from my parents (3)	Blank (0)	This pair correctly listed two inherited traits.
Pair 2A5 I have brown hair like my mom, I have the same nose as my mom. (3)	Blank (0)	The student mentions two traits that resemble her mother, an out-of school experience being used to explain the response.
Pair 2A6 My friend has brown hair, blue eyes are some traits I have inherited from my mom and dad I have inherited blonde hair from my mom, and tallness from my dad. (3)	Blank (0)	One of the pair attributes height to his dad and hair color to his mother. The pair used their out-of-school observation to support their claims.
Pair 2A7 I am short from my mom and eye color from my dad. I have short legs from my dad and freckles from my mom. (3)	Blank (0)	This pair attributed certain inheritable traits to a specific parent and indicator that they are using their out-of-school funds-of-knowledge
Pair 2A8 The ability to roll my tongue – my partner I have two different colored eyes (2)	Blank (0)	Though this pair correctly list inheritable traits, it was not clear what they meant by having two different colored eyes
Pair 2A9 I have inherited my looks and my blue eyes from my dad. (2)	Blank (0)	This response was vague because it was not clear what was meant by 'looks'. The eye color was attributed to a parent an indication of use of out-of-school experiences and observations.
Pair 2A10 Eye color and hair color (3)	Blank (0)	This pair list two traits that can be inherited from parents
Pair 2A11 I have brown hair, straight hair, freckles. She has brownish blonde hair, hazel eyes, straight hair (3)	Blank(0)	Each of the students in this group listed the traits they inherited from their parents
Pair 2A12 Hair colors, freckles, eye colors. (3)	Blank (0)	The students list inheritable traits

Table 5.5 cont'd

Pair 2A13 Blank (0)	Blank (0)	This pair did not respond to both scaffolding support prompts
Pair 2A14 J has Freckles, eye color, height and S has eye color, height, musical ability (3)	Blank (0)	The students included acquired traits and heritable traits that are influenced by the environment
Pair 2A15 Yes, skin color, hair, and height. (3)	Blank (0)	Students list heritable traits

In each Table with examples of students' responses, I make a comment about the response. As shown in Table 5.5 above, none of Ms Adams' students in the second hour responded to scaffolding support item 4 that appeared at the end of the activity. About 50% of the students tend to attribute an inheritable trait to a specific parent. In Table 5.6, I show some responses from Dr. Perry's students. These responses show a trend that is similar to Ms. Adams' students of attributing inherited traits to a specific parent. At can be inferred that at least 50% of the students used their out-of-school funds-of-knowledge (the parent they look like) to explain their responses. In other words, students used their first space funds-of-knowledge as they created their third spaces that were hybrids of the different funds-of-knowledge.

Table 5.6

Examples of Students' Responses to Item 1and 4 (Dr. Perry's Second Hour)

Item 1 and 4 What are some traits that you have inherited from your parents? Ideal response Examples are eye color, skin color, natural hair color and texture, freckles, dimples, PTC (Phenylthiocarbamide) tasting		
Item 1. Pre-activity	Item 4. Post-activity	Comment

Table 5.6 cont'd

Pair 2P1 J-straight hair from my dad, the same color eyes as my dad. I also have my mom's mouth. A-wavy hair from my mom and brown hair from my mom. Also same nose from my mom. (3)	Blank (0)	Though the students identified inherited traits, they attribute the traits to a specific parent – based on their out-of-school observations and funds of knowledge
Pair 2P2 N- I have inherited my parents singing and my moms hair and my dads lips my moms nose and my dad's butt that's pretty much it. C- I have inherited my mom's singing umm my dad's hair line, umm my mom's nose and eyes, umm my dad's lips umm that is pretty much it. (2)	Blank (0)	The students also listed traits that can be learned such as singing and they attributed all heritable traits to specific parents - based on their out-of-school observations and funds of knowledge
Pair 2P3 Blank (0)	Blank (0)	This pair of students did not respond to both prompts
Pair 2P4 Fast growing nails, brown eyes, and brown skin. P- light brown eyes, brown hair, white skin (3)	Fast growing nails, brown hair, black hair, long hair, short hair (3)	The pair listed fast growing nails before and after the activity though nail growth can also be influenced by diet.
Pair 2P5 Blank (0)	Blank (0)	The students did not respond to the scaffolding prompts
Pair 2P6 Hair, skin and teeth (2)	Hair (2)	This pair is just listing traits without elaboration. The student not identify if they meant hair color or skin color.
Pair 2P7 Dark skin, brown eyes, curly hair (3)	Blank (0)	Students correctly list inherited traits
Pair 2P8 A- eye color, face J- dad's eye color, dad's skin color (3)	Blank (0)	Though the pair lists inherited traits, they attribute them to a specific parent
Pair 2P9 I inherited brown eyes from both parents and dark hair from my dad (3)	Blank (0)	The response phrasing suggests that one student wrote it. The response indicate that the student's eye color looks like that of both parents' - based on their out-of-school observations and funds of knowledge

Table 5.6 cont’d

Pair 2P10 Hair color, eye color, skin color, height, and health conditions. (3)	S- skin color, hair color, eye color A- brown hair, brown eyes, skin color, height facial features (3)	It was not clear what students meant by ‘health conditions’, maybe they were referring to inherited diseases. Height though inherited, it is also influenced by the environment
Pair 2P11 A- bad eyes, small, hair brown eyes J- brownish/blondish, hair smarts, good looks, green eyes (3)	Blank (0)	This pair lists inheritable traits though they included some features that were not very clear on what they really meant, for example ‘good looks’ or ‘small’ or "smarts"
Pair 2P12 Your hair texture and color, eye color, and skin color. (3)	Blank (0)	This pair clearly listed traits that can be inherited
Pair 2P13 *R*- head structure, hair color, eye color M- nose structure, eye color, hair color (3)	Blank (0)	Each of the pair lists three traits heritable from parents
Pair 3P14 Brown Eyes- Dad Mixed Skin- Both Brown Hair- Dad Height- Mom Speed- Both (3)	Blank (0)	It was surprising that it was only the skin color that the pair mentioned as mixed and from both parents. Other than that, they attributed the rest of the heritable traits to specific parents - based on their out-of-school observations and funds of knowledge

A sizeable number (56.9%) of Dr. Perry’s students did not respond to item four. A couple of students who attempted to respond to both item 1 and 4 provided similar responses to both, (see table 5.6 above).

Students taught by the two teachers had similar patterns of responses that attributed certain traits to have been inherited from a specific parent. The students’ explanations do not indicate full understanding of how alleles are passed from parents to offspring. In my view, attributing a heritable trait to a specific parent may influence the way students understand how parents who may be both heterozygous for a certain trait may have children that are different from both parents.

Based on my analysis of students' responses, students had partial understanding of the mechanisms of inheriting alleles from both parents even after interacting with the WISE unit. The idea that students identify a parent from which they say they inherited a particular trait from may be just suggesting that they resemble a parent for a specific trait. It can be deducted from students' responses that students believe each parent contribute 'genes' for a particular trait. However, it can also be inferred that, although students may articulate that they inherit features from both parents, they do not necessarily understand that the expression of each phenotype is dependent on two alleles; one allele from the mother and the other from the father.

Students who attributed an inheritable trait to a specific parent seemed to believe that offspring inherit only from the parent they resemble for that feature as if each parent passes on genes for specific traits. In this study, it was not possible to state with certainty the students' thinking when they attribute inherited traits to specific parent. However, I noted that some mixed race students (see example Table 5.6 pair 3P14) attributed their skin color as having been transmitted from both parents to offspring and not other traits they listed. Such students' reasoning suggests that students believe that they inherit from a parent from whom they resemble for that particular trait. It can be argued that these students were drawing from their everyday observations and experiences to make explanations about genetic inheritance.

Attributing inherited traits to a specific parent maybe plausible to students based on their observations of resemblance to a specific parent. In this study, I refer to such attributions as students' '*resemblance theory'*. Such students believe that an offspring inherits a trait from a parent with whom they resemble (thus '*resemblance theory'*) to explain genetic inheritance. Students who listed a feature as from a specific parent drew their explanations from their out-of-school funds of knowledge. It is important to note here that despite having scaffolding support prompts that were within curricula texts, students continued to draw their evidence from their "first space" as they recreated their hybrid space.

If the majority of students truly believe that offspring inherit a particular trait from a parent they resemble, then such conceptual understanding might also have a bearing on why most students may rationalize that boys inherit more from their fathers and girls from their mothers based on gender resemblance. Such reasoning may influence the kinds of hybrid spaces the students create and their understanding of how heterozygous parents may have a homozygous recessive offspring for a particular trait. These findings are consistent with Karbgo et al. (1980)'s findings that some students do not understand that both parents contribute alleles for each inheritable characteristic. Karbgo and his colleagues pointed out that most students believe that one parent contributes genes for some characteristics and the other parent contributes genes for other features. This could explain the students' conceptual understanding when they indicated that they inherited certain features from a specific parent based on their observations of resemblance. In sum, students seem to use their out-of-school funds of knowledge, experiences and observations as evidence to support some of their scientific claims.

However, it is possible that when students identify the parent from which they thought they inherited the feature from they could have been simply implying that they observed that for certain features they resemble one parent more than the other. This view may mean that students could have been referring to observable physical appearances without referring to origin of alleles that control the expression of the feature. Trait is simply defined as a characteristic or feature that can be either inherited or acquired. When students attribute a trait to a specific parent, it is possible that they may be simply showing that they understand that one can inherit features from parents and that for a specific trait they resemble a certain parent more than the other. For example, a student may say they got dimples from their father and not their mother referring to their accurate observations that they resemble the father and share the same feature with their father. It is important to have curricula scaffolding that require students to explain their reasoning in order to accurately capture their thinking and how they make connections between concepts. Hence the importance of examining students' responses holistically so as to gather more information about students' reasoning and understanding about genetic inheritance.

Next, I highlight students' responses on items that asked students if boys or girls inherit more from fathers or mothers respectively.

Items 2 and 3 (5&6). Items two and three were designed to enable students to make their thinking visible by responding to prompts that asked if boys or girls inherit traits more from their fathers or mothers respectively. Items 2 and 3 were the same as 5 and 6 respectively. Items 5 and 6 appeared after the activity to allow students who wanted to revise their earlier claims. Table 5.7 below depicts the frequencies for each score to scaffolding prompts 2 and 3 (including 5 & 6). As per KI rubric, students were awarded a score of one if they had a misconception. For example, students would score a one if they indicated that it was true for boys or girls to inherit more genes from their fathers or mothers respectively (see rubric in Table 5.7).

Table 5.7

Frequencies of Students' Ideas on Gender Resemblance and Inheritance

Scores	Item 2. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer (pre activity)		Item 3. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer (pre activity)		Item 5. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer (post activity)		Item 6. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer (post activity)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
0	24	16.6	28	19.3	100	69.0	101	70.1
1	38	26.2	37	25.5	7	4.8	7	4.9
2	47	32.4	45	31.0	20	13.8	19	13.2
3	23	15.9	22	15.2	10	6.9	10	6.9
4	12	8.3	12	8.3	7	4.8	7	4.9

Table 5.7 shows the score frequencies to items 2, 3 5 and 6. Students scored a zero if they did not make an attempt to respond to the question. In this case, students scored a one if they said it was true that boys (or girls) inherit more genes from their fathers (or mothers) than their mothers (or fathers). Students scored a four for providing scientifically accurate and valid claims supported by appropriate evidence (see rubric example in Table 4.2). The number of students who did not respond to repeated scaffolding support prompts was about 70%. That made it challenging for me to compare students' claims on repeated items. Furthermore, non-response to repeated scaffolding support prompts undermined the design principles that rationalized repeating questions.

Fisher and Moody (2000) pointed out that, alternative conceptions (misconceptions) in different biology domains are widely shared by many and often held by at least 20% of the student population. Analysis in this study suggests that 26% of students believe that boys inherit more from their fathers and also that girls inherited more from their mothers than their fathers (see Table 5.7 above). Most students did not respond to prompts when they appeared for the second time. However, those who responded to the repeated questions did not change their claims (e.g. two pairs in Table 5.6 above). Table 5.8 below shows some descriptive statistics for items 1 through 6. The mean represents the average score obtained by the students for a specific item. For example, on item 1 (Q1 in Table 5.8 below) the average score was 2.22 where possible scores ranged from zero to three. Also for item two, the mean was 1.72 and the possible scores ranged from zero to four (see Table 4.5, Chapter 4). Still, not much can be learned about students understanding by comparing the mean score of repeated questions because most students skipped repeated questions.

Table 5.8

Descriptive Statistics for Items 1 Through 6

Paired Samples Statistics

		Mean score	N	Std. Deviation	Std. Error Mean
Pair 1	Q1	2.22	145	1.108	.092
	Q4	.83	145	1.286	.107
Pair 2	Q2	1.72	145	1.171	.097
	Q5	.72	145	1.216	.101
Pair 3	Q3	1.66	145	1.197	.099
	Q6	.71	145	1.213	.101

The number of student pairs who participated in the study was 145 (see table 5.8 above). The descriptive statistics for items depicted in table 5.7 above show that the pre activity means (items 1, 2 and 3) were higher than post activity means (items 4, 5 and 6 respectively). Paired *t*-tests suggest that these differences were highly significant (see table 5.9 below). However, the mean differences could have been a result of students not attempting to respond to items that appeared for the second time as post activity (for example table 5.7 above). Although the *t*- test statistical analysis may not mean much in terms of accuracy of students' responses, the findings have a significant meaning from a curriculum development and instructional practices stand points. The findings raise questions on whether the curricula scaffolds are being utilized as anticipated by designers of the unit.

Table 5.9

Paired T-test for Items 1 through 6

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean Score	Std. Deviation	Std. Error Mean	Lower	Upper	*t*	DF	Sig. (2-tailed)
Pair 1	Q1 – Q4	1.386	1.492	.124	1.141	1.631	11.191	144	.000
Pair 2	Q2 – Q5	.993	1.320	.110	.776	1.210	9.058	144	.000
Pair 3	Q3 – Q6	.952	1.325	.110	.734	1.169	8.652	144	.000

Tables 5.10 and 5.11 below show students' responses to scaffolding support prompts on how boys and girls inherit from their fathers and mothers. Literature indicates that some student believe that boys inherit more of their features from their fathers than their mothers and also that

girls inherit more from their mothers that their fathers (e.g., Berthelsen, 1999). Items 2, 3, 5 and 6 were designed to solicit these possible beliefs that students may have.

Table 5.10

Examples of Ms. Adams' Students' Responses to Item 2, 3, 5 and 6

<table>
<tr><td colspan="5">Item 2 and 5
Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer
Item 3 and 6
Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer
Ideal response
False, offspring inherit from both parents. They get half from the mother and the other half from the father. Meiosis produces sex cells that have ½ chromosome number, when sex cells unit during reproduction the resulting offspring end up with a full set of chromosomes</td></tr>
<tr><td>Item 2. Pre activity response</td><td>Item 5. Post activity response</td><td>Item 3. Pre activity response</td><td>Item 6. Post activity response</td><td>Comment</td></tr>
<tr><td>Pair 2A1
Z-True- all boys are strong and look like their fathers (1)
S-False- my brother inherited more traits from my mother (2)</td><td>Blank (0)</td><td>Z-True- I look more like my mom (1)
S-False- I look like both (2)</td><td>Blank (0)</td><td>One of the students said it was true that boys and girls inherit more from their fathers and mothers respectively. However, though the other student said it was false, the explanation does not show understanding that offspring inherit equally from both parents.</td></tr>
<tr><td>Pair 2A2
IDK (0)</td><td>Blank (0)</td><td>IDK (0)</td><td>Blank (0)</td><td>This pair indicated that they did not know on pre-activity and did not attempt the post-activity item. However, on item 1, they attributed features to a specific parent</td></tr>
<tr><td>Pair 2A3
We think this is true because they are of the same gender, so they will inherit the boyish</td><td>Blank (0)</td><td>We think this is true because girls will inherit the girlish traits from their</td><td>Blank (0)</td><td>This pair believes that it is true boys that boys inherit more from their fathers and girls inherit more from their mothers. They explain that girls get girlish looks from mothers. Such</td></tr>
</table>

Table 5.10 cont'd

traits from their father (1)		mother (1)		interpretation does not show understanding of how sex determining genetic information is passed from parents to offspring
Pair 2A4 False because it is a 50-50 chance because if your mom has a dominant gene and you are a boy then you would still get a dominant gene whether from your mother or your father (3)	Blank (0)	False for the same reason as above (False because it is a 50 – 50 chance because if your mom has a dominant gene and you are a boy then you would still get a dominant gene whether from your mother or your father (3)	Blank (0)	Though this pair explained that offspring inherits from both parents, they seem to suggest that it's the dominant alleles that are passed on. It can be inferred from this response that this pair believes that it is the dominant allele that is passed and expressed in offspring
Pair 2A5 False, children inherit traits equally from each parent (4)	Blank (0)	False, children inherit traits equally from each parents regardless of sex (4)	Blank (0)	These students show understanding that offspring inherit from both parents
Pair 2A6 I do not think that this is false because you should get an even number of traits from both parents (2)	Blank (0)	I do not think that this is false because you should get an even number of traits from your parents (2)	Blank (0)	The students' explanation suggests that they have an idea on inheriting from both parents. They have mixture of normative and non-normative ideas because their response suggests that they believe it is true that boys inherit more from their fathers than their mothers
Pair 2A7 I do not know because my brother looks a lot more like my mother (2)	Blank (0)	I do not know but I look like my dad more than my mom (2)	Blank (0)	The student draws from her personal family experiences that his/her brother resembles their mother more than their father. The student observed some cross gender resemblance

Table 5.10 cont'd

Pair 2A8 I think this is true because (1)	Blank (0)	Blank (0)	Blank (0)	This student believes it is true that boy inherit more from their fathers but did not explain their thinking
Pair 2A9 I do not think so because you get your genes from both your mom and your dad (3)	Blank (0)	I do not think so, again you have genes from both parents (3)	Blank (0)	Student does not elaborate on parental equal contribution for each trait
Pair 2A10 False because you inherit equal parts from both parents (3)	Blank (0)	False because you inherit equal parts from both parents (3)	Blank (0)	The pair gives a correct response although it is not very clear what they meant by 'equal parts'
Pair 2A11 We have agreed (my partner and I) that we are not sure (0)	Blank (0)	We have agreed (my partner and I) that we are not sure (0)	Blank (0)	These students did not know the answer to the scaffolding prompts
Pair 2A12 Well, it is most likely not true because everyone has an even chance of getting the same gene as another family member female or male (2)	Blank (0)	The possibilities can even out between two parents because of this girls can look and act like their mother or their father (2)	Blank (0)	Students show mixture of ideas and seem to suggest that the way people 'act' could be inherited
Pair 2A13 True (1)	Blank (0)	Blank (0)	Blank (0)	Though they did not elaborate, this pair believes that it is true that boys inherit more from their fathers than their mothers
Pair 2A14 No, they receive traits from both their mom and dad. Maybe sometimes more than the other but not necessarily always (2)	Blank (0)	No, they receive traits from both their mom and dad. Maybe sometimes more than the other but not necessarily always (2)	Blank (0)	Response indicates that students have limited understanding on how traits are passed on from parents to offspring

Table 5.10 cont'd

Pair 2A15 True because he is a boy and he is most likely to have more inheritance they are the same gender (1)	Blank (0)	True because the girl is same gender as her mom (1)	Blank (0)	These students believe that gender resemblance has something to do with inheriting 'more' from one parent.

A sizeable number (26.2%) of the students in this study believed that it was true that boys (or girls) inherit more traits from their fathers (or mothers) than their mothers (or fathers). An interesting pattern was that all students stated 'true' for items 2 and 3 also attributed certain traits to have been passed onto them from a specific parent on items 1 and 4. In other words, their explanations were based on resemblance.

Students' responses in Tables 5.10 and 5.11 indicate that they did not have coherent understandings about how inheritable traits are passed on from parents to offspring. The trend was similar for students taught by two different teachers. That is, students were not supporting their claims using evidence from the WISE unit or any other scientific source. Rather, it was evident that students explain their responses using their own, what they thought to be plausible, personal experiences. For example, some students' explanations indicate that having same gender with a parent implies that the offspring gets more traits from a parent whose gender is the same as theirs thus seemingly using the resemblance theory to explain their responses.

Table 5.11

Examples of Dr. Perry Students' Responses to Items 2, 3, 5 and 6

Item 2. Pre activity response	Item 5. Post activity response	Item 3. Pre activity response	Item 6. Post activity response	Comment
Item 2 and 5 Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer Item 3 and 6 Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer Ideal response False, offspring inherit from both parents. They get half from the mother and the other half from the father. Meiosis produces sex cells that have ½ chromosome number, when sex cells unit during reproduction the resulting offspring end up with a full set of chromosomes				
Pair 2P1 False because Jillian inherited more from her father. (2)	Blank (0)	False because all the traits even out in some way. (2)	Blank (0)	This pair of students does not have coherent understanding of how traits are inherited from parents
Pair 2P2 N- no not really but again yes because the mom has more mother in her and the dad has more father in him and more of his looks to give the son C- same as N's (2)	Blank (0)	N- Not really because I myself inherit more from my father that from my mother but again I do also inherit a lot from my mom. C- Not really because I look more like my mom but my cousins mostly look like their dads even though they are girls. (2)	Blank (0)	Despite their understanding of inheriting from both parents, these students have mixed ideas about gender and resemblance

Table 5.11 cont'd

Pair 2P3 Blank (0)	Blank (0)	Blank (0)	Blank (0)	The pair did not respond to the prompts
Pair 2P4 False, because sometimes like the rr, boys can inherit more from their mothers, like blue eyes and freckles and things like that. (2)	No, it depends on the dominance in the genotype (2)	False, because sometimes like the rr, girls can inherit more from their fathers, like brown eyes and no freckles and things like that. (2)	No, it depends on the dominance in the genotype (2)	These students' explanations show that they do not have coherent understanding of how dominant and recessive alleles are passed from parents to offspring. They are suggesting that one inherits more genes from the parent they resemble
Pair 2P5 Blank (0)	Blank (0)	Blank (0)	Blank (0)	This student pair did not respond to the scaffolding prompts
Pair 2P6 True because they have the same gender (1)	True because they have the same gender (1)	True because they have the same gender (1)	True because they have the same gender (1)	It was evident that the pair held on to their conceptions that boys inherit more from their fathers than their mothers because of gender even after instruction
Pair 2P7 Maybe depends on the statistics because the parents could be almost exactly the same then the child could get the same amount of traits from both parents (2)	Blank (0)	Maybe depends on the statistics because the parents could be almost exactly the same then the child could get the same amount of traits from both parents (2)	Blank (0)	This pair does not have coherent understanding of the concepts of passing on genetic information from parents to offspring
Pair 2P8 False (2)	Blank (0)	True (1)	Blank (0)	Though they did not give an explanation, this pair thought it was true for girls and not for boys.

Table 5.11 cont'd

Pair 2P9 I think that is false because boys can inherit traits from there moms like eye color and hair color (3)	Blank (0)	Same here girls can inherit trait from their dads like me I got dark hair from my dad (3)	Blank (0)	These students do not have coherent understanding on passing on of genetic traits from parents to offspring
Pair 2P10 False, The mother could have a dominant gene that would over power a recessive gene. (3)	False, the mother could have a dominant gene that would over power a recessive gene.(3)	False, the father could have a dominant gene that would over power a recessive gene. (3)	False, the mother could have a dominant gene that would over power a recessive gene.(3)	Students have same response for before and after activity scaffolding prompts
Pair 2P11 Yes because we acquired more genes from our fathers to make us boys and girls acquire more genes from their moms to make them girls the circle of life people!!!! Come on!!!! (1)	Blank (0)	Yes because they acquire more from them to make them girls (1)	Blank (0)	The pair believes that sex determining alleles account for the amounts of alleles they get from the parent they share same gender with
Pair 2P12 False, because your mom could have had the dominant genes which she passed on to her son. (3)	Blank (0)	false, because her dad could have carried the dominant genes which he passed on to his daughter.(3)	Blank (0)	The response seem to suggest that its only the dominant alleles that get to be passed to offspring

Table 5.11 cont'd

Pair 2P13 I do not know –MS False the mother because she has the dominant gene. –MA (2)	Blank (0)	I do not know –MS I do not know –MA (0)	Blank (0)	Though the students are not sure, they seem to have the conception that it's the dominant allele that gets to be passed from parents to offspring

The pattern of responses was the same for students taught by the two teachers. It is important to restate that 26.2% of the students indicated that it was true that boys inherit more traits from their fathers than their mothers. 32.4% scored a two (2) suggesting mixture of normative and non-normative ideas. For example, students scored a two after they indicated that it was false that boys inherit more traits from their fathers than their mothers but went on to suggest that it was 'the dominant gene that gets to be passed on'. Such a response suggests that those students believe that only the dominant alleles are passed from parents to offspring and that all phenotypic appearances are a result of dominant alleles. In this study, 58.6% responses suggest that students had some difficulty in understanding how traits are passed on from both parents to offspring. These were students who scored a one or a two on items 2 and 3 - this does not include those with zeros because they did not make their thinking visible by responding to the scaffolding prompts. Their responses point to students' obscurity in comprehending issues of parental resemblance including gender, passing on of recessive and dominant alleles and how that relates to genetic inheritance from both parents. Students in this study were making their explanations using out-of-school funds of knowledge based on their life experiences and observations. For example, hair color, eye color and gender resemblance to one of their parents made them believe that the specific parent was the only parent passing on alleles that control the trait. This is because they could not visualize this abstract phenomenon of genetic contribution from a parent they may not have resemblance for a specific inheritable trait. For example, students may fail to comprehend how a female offspring may also receive a sex determining allele from a male parent or male offspring inheriting form female parent. Such students explanations are not random or arbitrary but rather represent a pattern that is plausible to the learners who try to make sense of the world limited scientific knowledge (e.g. Fisher & Moody, 2000). What was surprising in this study is how students did not bother referring to text provided in the WISE curriculum unit as they responded to the scaffolding prompts. This maybe because the students did not bother to revisit curriculum text or it could be an instructional issue where they were not adequately guided on how to make use of the embedded scaffolding support prompts. The students continued to use their out-of-school observations and funds of knowledge to support their claims. About 15% of student pairs' responses to items 1 through 6 suggest that they created a hybrid space and knowledge webs that showed understanding of concepts tested by the items; these were students who scored at least a 3 on these items.

Despite the students' understanding that offspring inherit traits from both parents, a sizeable (58.6% of those who responded to items 1 through 3; and 19% of those who responded to items 4 through 6) number had isolated ideas on how alleles are passed from parents to offspring. However, it is important to restate hear that about 70% of students did not respond to items 4 through 6 as compared to about 18% who did not respond to items 1 through 3. Analysis of students' responses (for example Tables 5.10 & 5.11 above) illustrate that some students believe that offspring inherit 'dominant alleles' from a specific parent that they resemble implying that one inherits bits and pieces of alleles controlling phenotypic expression for specific traits. This finding is similar to what was documented by other researchers (e.g. Driver, et al.1994; Karbgo et al., 1980). In their responses, some students indicated that only dominant traits (probably referring to alleles) get to be passed on from parents to offspring. This may simply mean that the students could have been trying to explain that a dominant allele may musk a recessive allele resulting in the expression of dominant allele. However, such a response may also imply that the students may believe that the phonotypic features are only a result of an offspring having received only dominant alleles only. Additionally, it can be inferred that students with such beliefs may find it challenging to comprehend how parents that are heterozygous for a certain trait may have a homozygous recessive offspring; an offspring that is looks different from both parents for that trait. Such responses imply students' misconceptions on the relationship between dominant and recessive alleles as they relate to genotype and phenotype of organisms. Consequently, this prompted me to explore students' understanding about genes and alleles as they relate to the phenotype and genotype of offspring.

Students Conceptions on Relationship between Genes, Genotype and Phenotype

Item 7. Item 7 was a scaffolding support prompt embedded in activity 4 titled 'The Mechanisms of Sexual Reproduction'. The item was designed to enable students to make their thinking visible as they reflected on science concepts they would have learned as they interacted with the WISE unit. Students were expected to draw their claims and explanations from the WISE curriculum because the scaffolding support prompts appeared after students had done activities covering concepts asked in item 7. Table 5.12 below represents examples of students' response to item 7. I randomly selected one class hour from Dr. Perry's students to illustrate examples of students' thinking. I did not select examples from the other teacher's class because her students had similar responses – as highlighted in subsections above in this chapter. Nonetheless, students in both teachers' classes had similar patterns of responses (for example their responses to items 1 to 6). Therefore, it can be cautiously inferred that patterns noted in Dr. Perry's class responses could be common amongst students in this study.

Table 5.12

Examples of Dr. Perry's Students' Conceptions on Genes, Alleles as they Relate to Genotype and Phenotype

Item 7 How are organism's genes and alleles related to its genotype and phenotype? Ideal response Alleles are different forms of genes. A gene is a functional unit of heredity. Genotype is the genetic make-up of an organism whereas phenotype is the physical appearance of an organism as determined by its genotype	
Students' responses	Comment
Pair 5P1 They are related because they are directly responsible for the external appearance (phenotype) and the genes (genotype). The genes and alleles vary between parent genes but alleles contain multiple possibilities for traits to occur in the offspring (3)	Though the student shows some understanding, the explanation does not show comprehensive conceptual understanding and relationships between concepts especially on relationship between genes and alleles
Pair 5P2 They are related because they each bear the outcome of the way something someone or how a person is going to come out in life. Like eyes can be totally different from their parents or they can have the same features of their parents. Recessive gene cannot be real gene without another recessive gene and the dominant gene is a dominant gene that is a gene just with one (2)	The students confuse 'gene' and phenotype. They seem not to understand alleles and their role in genotype and phenotype expression
Pair 5P3 An organisms' gene determines its genetic traits, the organisms' alleles are the genes of its parents, combining both alleles gives information to what genes contains and its phenotype (2)	The students have isolated ideas about the relationship between genes, alleles, genotype and phenotype

Table 5.12 cont'd

Pair 5P4 Genes make up the genotype and phenotype and alleles are the gene types. Example, the genotype make up what genes are in the body making a person who they are. Phenotypes are the genes that people can see like eye color, hair color and skin color (2)	The response does not show coherent understanding of the concepts. The student seem to suggest that a gene is the same as phenotype
Pair 5P5 Genes and alleles are related because genes and alleles are the traits and genotypes and phenotypes are how they are categorized. For example, someone has the alleles and phenotype for brown eyes (2)	Students have isolated ideas about the relationship between concepts
Pair 5P6 The genes are related to genotype because they hold the trait. They make the genotype possible. The alleles are related to genotype because the alleles hold the different versions of the trait, for example the rose gene has the alleles for red color and white petal color that the plant could have RR, Rr or rr. The genes are related to the phenotype because the genes hold the alleles that determine what the phenotype is. The alleles are related to the phenotype because they contain the information that determines the phenotype (2)	The students illustrate an understanding of alleles but do not show coherent understanding of genotype and phenotype as they relate to genes and alleles
Pair 5P7 Genes and alleles make the genotype, and the phenotype is the end that comes out how you are going to look (3)	The students show understanding of genotype and phenotype though they do not distinguish between genes and alleles
Pair 5P8 Genes determine alleles and genotypes determine phenotypes. Without the genes, the alleles would not matter or exist. Genotypes are every similar to genes too. The phenotype is part of a gene. It is the color that makes the genes what they really are (2)	Students show mixture of ideas and fail to provide a coherent relationship. Students do not understand the difference between genes and phenotype

Table 5.12 cont'd

Pair 5P9 If you look at the word genotype, you see first 3 letters gen. Alleles is the color of the plant. The first letters of that is pen. The three genotypes are, I am using the letter R: RR. Rr and rr. Here is an example: organisms could have a mother and father that have two offspring. The first offspring have a genotype of Rr. The second has rr. They are different. (2)	The students show lack of understanding of the relationship between genes, alleles, phenotype and genotype. They are confusing allele and phenotype. Though the response is rather confusing, they scored a 2 because the pair attempted to explain using an example on color of flowers that was in the unit
Pair 5P10 Genes and alleles are related to genotypes and phenotypes. Genotypes and phenotypes are related to genes and alleles by the fact that genotypes are organism's particular amount of alleles, which are different types of genes and phenotypes are the way traits are shown as expression of the organism. Traits are like genes, so I guess that is how they are related (2)	Students show isolated ideas about the relationship between the concepts of genes, alleles, genotype and phenotype
Pair 5P11 Blank (0)	There was no attempt to respond to the question

Whereas a gene can be viewed as basic instruction or sequence of DNA, an allele is a variation of that instruction. Inherited characteristics are determined by specific genes and most genes have two or more variations of their kind called alleles. For example, a gene for freckles has two alleles. One allele is for freckles and the other allele is for no-freckles. This means that an individual may inherit two different or two identical alleles from their parents. The two alleles interact in specific ways (dominant or recessive) that determine the physical appearance of the offspring. For example, a dominant allele for freckles can be represented by an 'F' and a recessive allele by and 'f'. Offspring may have a genotype of 'FF', 'Ff' or 'ff' having 'received' one allele from each parent. For the aforementioned genotypes, the first two results in offspring having freckles and the third genotype results in a child with no freckles. Students need to understand that for each of their traits (e.g. presence or absence of freckles), they got an allele from each parent irrespective of which parent they resemble. However, it is possible that students may conceptualize ‘inherited trait’ simply as observable parental resemblance which they consequently attribute to a specific parent.

Analysis of the students’ responses indicates that they had difficulty in distinguishing between a gene and an allele. Though learners in this study could define genotype, majority of them could not explain the relationship between alleles, genotype and phenotype. Students’ lack of full understanding on the relationship between alleles, genotypes and phenotypes may affect the way they explain the mechanisms of passing on of genetic material from parents to offspring. Although the students were explaining about unseen or abstract concepts such as genes and alleles, they continue to draw from their experiences. Item 7 responses suggest that some students were drawing their explanations or evidence to support their claims from both their personal out of school and in-school WISE curriculum experiences. For example, a pair with a mixture of normative and non-normative ideas stated “phenotypes are the genes that people can see like eye color, hair color and skin color” (see Table 5.12). Although the response showed a lack of understanding of what genes are, just like some of their peers, the pair gave examples they could relate to. Table 5.13 below shows the students’ score frequencies as measured by the KI rubric.

Table 5.13

Item 7 Overall Score Frequencies

Q7

	Score	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	54	37.2	37.2	37.2
	1	16	11.0	11.0	48.3
	2	38	26.2	26.2	74.5
	3	33	22.8	22.8	97.2
	4	4	2.8	2.8	100.0
	Total	145	100.0	100.0	

Thirty seven percent of student pairs in this study did not respond to the scaffolding support item 7. About the same number of students (37%) still had a mixture of normative and non-normative ideas after instruction (score of 1 or 2 in table 5.13 above). Only 2.8% of the student pairs scored a four on item 7 as per KI rubric. It is important to note that about 25% of the students provided scientifically complete responses (score of 3 or 4, table 5.13). Table 5.14 below shows item 7 frequencies broken down by teacher.

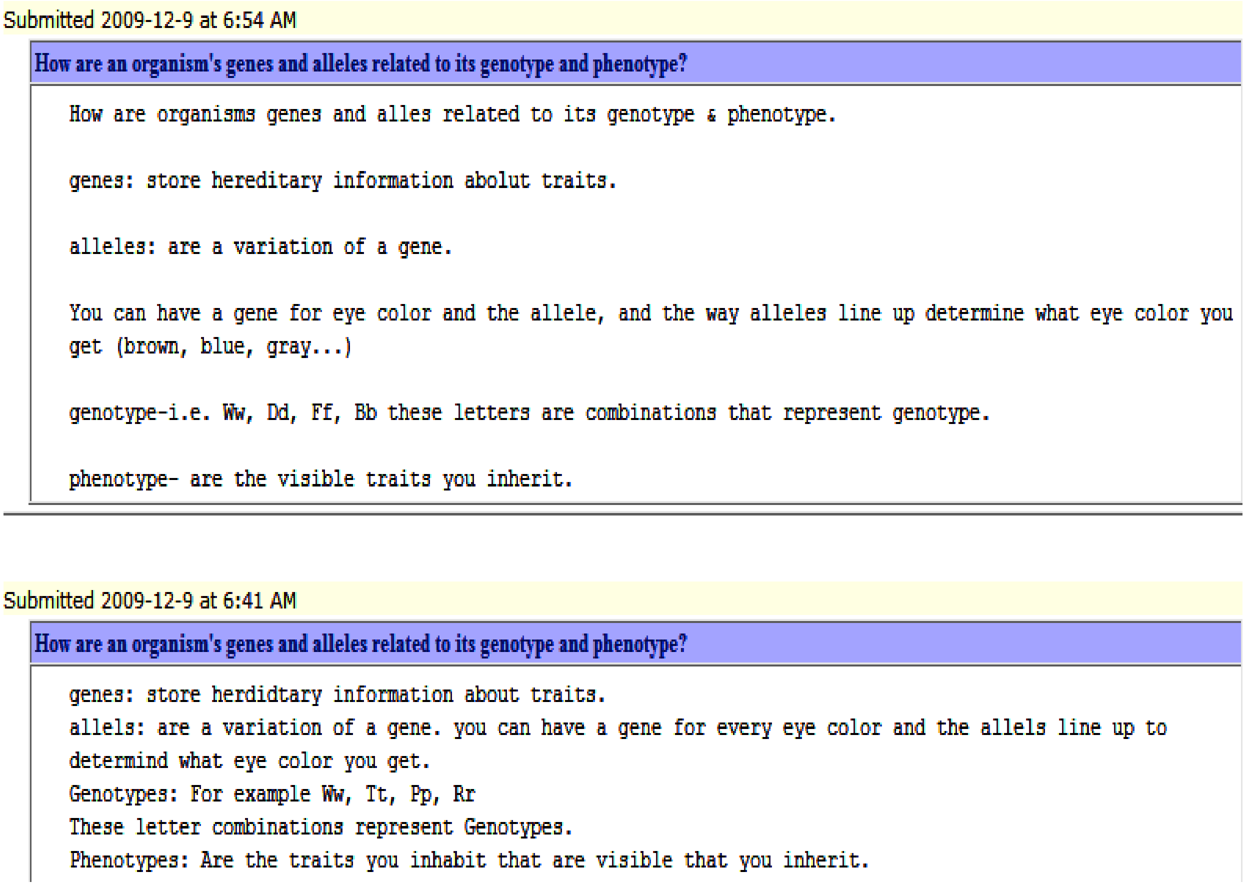
Table 5.14

Frequencies of Item 7 Broken down by Teacher

Q7

Teacher		Score	Frequency	Percent	Valid Percent	Cumulative Percent
Ms Adams	Valid	0	50	68.5	68.5	68.5
		1	0	0	0	68.5
		2	3	4.1	4.1	72.6
		3	20	27.4	27.4	100.0
		4	0	0	0	100.0
		Total	73	100.0	100.0	
Dr. Perry	Valid	0	4	5.6	5.6	5.6
		1	16	22.2	22.2	27.8
		2	35	48.6	48.6	76.4
		3	13	18.1	18.1	94.4
		4	4	5.6	5.6	100.0
		Total	72	100.0	100.0	

All of Ms Adams student pairs in hour 4, 5 and 6 (three out of five classes) did not respond to item 7 contributing to the 68.5% of her students who scored zeros as shown in Table 5.14 above. Amongst Ms Adams' students, only second and third hour students responded to item 7. However, majority of Ms Adams' students who responded item 7 scored a three. None of her students scored a four. As I explored responses submitted by Ms Adams' hours 2 and 3 students, it was evident that they had similar responses. For example, Figures 5.5 and 5.6 depicts responses from Ms Adams' hour 2 and 3 respectively.



Submitted 2009-12-9 at 6:54 AM

How are an organism's genes and alleles related to its genotype and phenotype?

How are organisms genes and alles related to its genotype & phenotype.

genes: store hereditary information abolut traits.

alleles: are a variation of a gene.

You can have a gene for eye color and the allele, and the way alleles line up determine what eye color you get (brown, blue, gray...)

genotype-i.e. Ww, Dd, Ff, Bb these letters are combinations that represent genotype.

phenotype- are the visible traits you inherit.

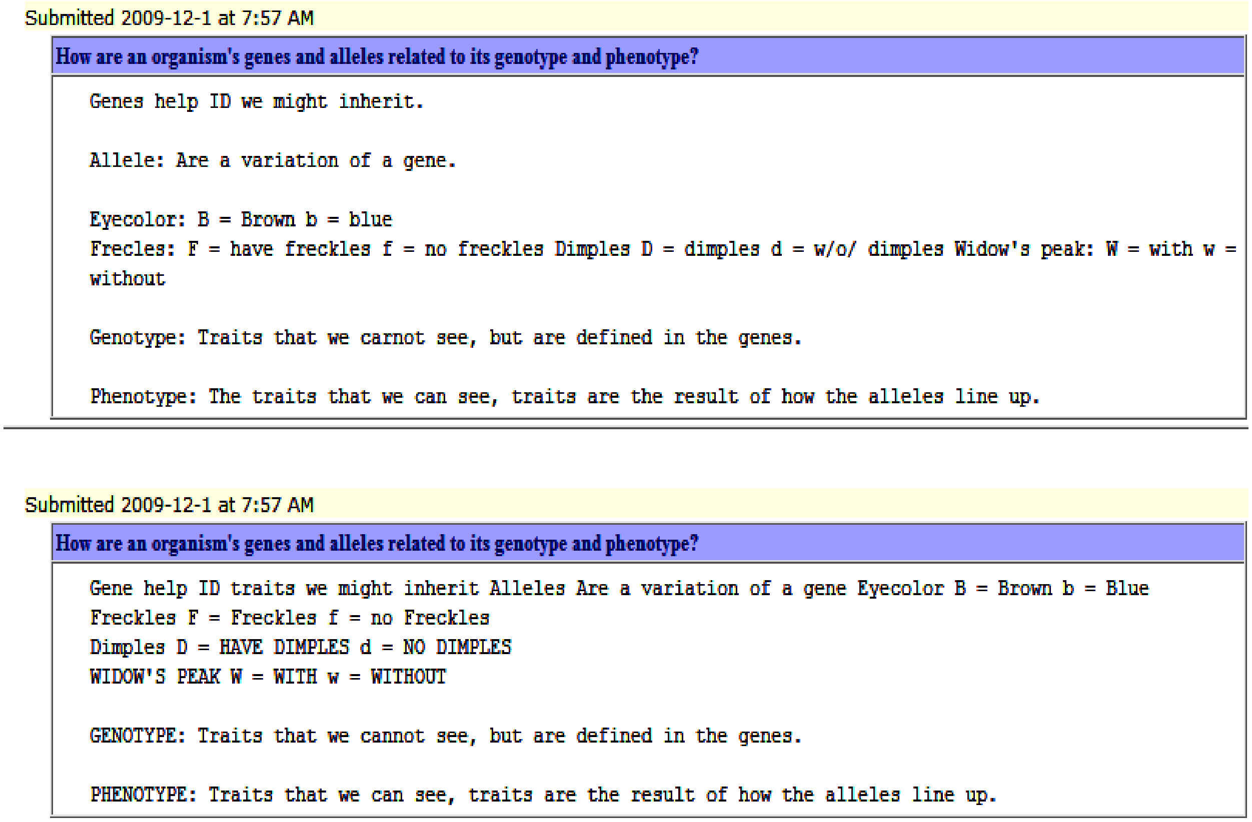
Submitted 2009-12-9 at 6:41 AM

How are an organism's genes and alleles related to its genotype and phenotype?

genes: store herdidtary information about traits.
allels: are a variation of a gene. you can have a gene for every eye color and the allels line up to determind what eye color you get.
Genotypes: For example Ww, Tt, Pp, Rr
These letter combinations represent Genotypes.
Phenotypes: Are the traits you inhabit that are visible that you inherit.

Figure 5.5. Example of Ms Adams' Second Hour Students' Responses to Item 7

Through my analysis, I found out that most of Ms. Adams' students had similar responses to item 7 (see Figure 5.5 above). The similarities of the responses suggest a possible influence of teacher scaffolds in assisting students as they responded to the online scaffolding prompts. A similar trend was observed in all of Ms Adams' classes as depicted in Figure 5.6 below; an example of responses from her third hour. The pictures showed recorded early hours because the WISE saver is hosted at the University of California, Berkeley, which is three hours behind the Eastern Time zone.



Submitted 2009-12-1 at 7:57 AM

How are an organism's genes and alleles related to its genotype and phenotype?

```
Genes help ID we might inherit.

Allele: Are a variation of a gene.

Eyecolor: B = Brown b = blue
Frecles: F = have freckles f = no freckles Dimples D = dimples d = w/o/ dimples Widow's peak: W = with w =
without

Genotype: Traits that we carnot see, but are defined in the genes.

Phenotype: The traits that we can see, traits are the result of how the alleles line up.
```

Submitted 2009-12-1 at 7:57 AM

How are an organism's genes and alleles related to its genotype and phenotype?

```
Gene help ID traits we might inherit Alleles Are a variation of a gene Eyecolor B = Brown b = Blue
Freckles F = Freckles f = no Freckles
Dimples D = HAVE DIMPLES d = NO DIMPLES
WIDOW'S PEAK W = WITH w = WITHOUT

GENOTYPE: Traits that we cannot see, but are defined in the genes.

PHENOTYPE: Traits that we can see, traits are the result of how the alleles line up.
```

Figure 5.6. Example of Ms Adams Third Hour Students' Responses to Item 7

Figure 5.6 above depicts examples of Ms. Adams' students' responses to item 7. Apart from having similar response, it can be seen from the picture above that Ms. Adams' students submitted their responses almost at the same time. This may suggest that the class was going through the unit at the same pace. This pattern was not the same for Dr. Perry's students (see for example Table 5.12 above depicting responses to item 7). Despite the fact that Ms. Adams' classes responded to item 7 giving similar claims, most of their responses were not complete as per KI rubric. Though the students distinguished between genes and alleles, the explanations about genotype and phenotype did not provide complete explanations on how genes and alleles are related to the organism' genotype and phenotype.

It is also important to note that Ms. Adams' students started having similar response from activity 4 (out of 8 activities) onwards. Consequently, I found it challenging for me to analyze the patterns of her students' responses because I was unsure whether to attribute responses to students or the teacher's scaffolds as from activity four through eight. Therefore the described patterns of students' responses for scaffolding support prompts that were embedded from activity four through eight were from Dr. Perry's students. This study was not about the teachers' instructional practices. However, I highlight some of the possible reasons for the observed differences in the manner in which students utilized the embedded scaffolding supports later in this chapter.

Next I examine students' understanding of the relationship between genes, chromosomes and DNA (item 9). Table 5.15 below show the frequencies of the students' scores broken down by teacher. About 82% of Ms Adams' student pairs did not respond to item 9 as compared to 14% of Dr. Perry's student pairs. Approximately 37% of Dr. Perry's students' responses suggest that they had full to complex understanding of the relations between chromosomes, genes and DNA after interacting with the WISE unit, they scored a 3 or a 4 (see frequency Table 5.15 below).

Table 5.15

Item 9 KI Score Frequencies

Teacher		Score	Frequency	Percent	Valid Percent	Cumulative Percent
Ms Adams	Valid	0	60	82.2	82.2	82.2
		1	2	2.7	2.7	84.9
		2	11	15.1	15.1	100.0
		3	0	0	0	100.0
		4	0	0	0	100.0
		Total	73	100.0	100.0	
Dr. Perry	Valid	0	10	13.9	14.1	14.1
		1	12	16.7	16.9	31.0
		2	22	30.6	31.0	62.0
		3	16	22.2	22.5	84.5
		4	11	15.3	15.5	100.0
		Total	71	98.6	100.0	
	Missing	System	1	1.4		
	Total		72	100.0		

Table 5.16 below shows examples of students understanding of the relationship between chromosomes, genes and DNA. Deep knowledge on the aforementioned concepts may enable students to gain some understanding on how alleles are passed on from parents to offspring.

Table 5.16

Examples of Dr. Perry's Fifth Hour Students Responses to Item 9

<table>
<tr><td colspan="2">Item 9
What is the relationship between chromosomes, genes and DNA (Dr. Perry, 5th hr)
Ideal response
DNA are the molecules that make genes. A gene is the unit of heredity and is a segment of a chromosome. Genes make up the chromosomes. A chromosome is a thread that holds many genes</td></tr>
<tr><th>Students' Response (KI score)</th><th>Comment</th></tr>
<tr><td>Pair 5P1
Genes contain specific types of information and are in chromosomes. DNA is the raw, precise data in the chromosomes. DNA also known as the double helix, basically makes up the chromosome. Chromosomes are compact structures used for carrying DNA and contain cells and DNA (3)</td><td>The student pair shows some understanding of the relationship but does not really elaborate on what genes are in relation to chromosomes. It was not clear what the pair meant by chromosomes containing cells, maybe they wanted to say genes.</td></tr>
<tr><td>Pair 5P2
DNA is basically how they are related. DNA is a collection of molecules. Chromosomes are a compact for carrying DNA cells. Genes are contained in chromosomes. A gene is a section of DNA strand that provides specific information needed for a specific trait (4)</td><td>This pair gave a near complete response but also mention what they call 'DNA cells' instead of DNA molecules. This suggests that students may be confusing cells with molecules.</td></tr>
<tr><td>Pair 5P3
Blank (0)</td><td>This pair did not respond to item 9.</td></tr>
<tr><td>Pair 5P1
Chromosomes and genes are two parts of DNA (1)</td><td>This pair does not understand the relationship between these concepts. They seem to suggest that a chromosomes is a part of DNA molecule</td></tr>
<tr><td>Pair 5P4
DNA is your genetic information. It carries the information needed to give you your traits. Genes are contained in chromosomes. Chromosomes are for carrying both DNA and genes and that's how they are related. (3)</td><td>Though the students show conceptual understanding, they did not distinguish between gene and DNA.</td></tr>
<tr><td>Pair 5P5
Chromosomes contain genes and genes contain DNA (4)</td><td>The response suggests that the pair have conceptual understanding of the relationship between chromosomes, genes and alleles</td></tr>
</table>

Table 5.16 cont'd

Pair 5P6 The chromosomes are made up of cells, and cells are made into genes, and genes consist of DNA (2)	This pair seems not to understand what cells are though they stated that genes consist of DNA.
Pair 5P7 Your genes in your chromosomes and your chromosomes are basically your DNA (2)	This pair views chromosomes, genes and DNA as the same thing.
Pair 5P8 Chromosomes are in DNA strands. DNA is the strands that store the 46 pairs of chromosomes that we have. Genes are also in DNA strands (1)	This pair shows limited understanding of the relationship between chromosomes, genes and DNA.
Pair 5P9 Well chromosomes are a combination of DNA and genes are contained in chromosomes (2)	Students' response shows that they have an idea about the relationship between genes and chromosomes but have a vague understanding on the relationship between DNA and genes.
Pair 5P10 Blank (0)	This pair did not respond to the item

In sum, a couple of responses show that students had difficulty in distinguishing between chromosomes, genes and DNA. This may be because of the way these terms are used in society at large. For example, 'it is in your genes' and 'it is in your DNA' are phrases often used when referring to either resemblance or individual's traits (Nelkin & Lindee, 2004). Rather than using evidence from the WISE unit to make their claims, a sizeable number of students continued to use their out-of-school observations and experiences to respond to the scaffolding support prompts embedded in the unit. The majority of students attributed certain inheritable features to a specific parent, and some showed limited knowledge on the relationship between DNA, gene, allele, chromosome, genotype and phenotype. As a result, I was curious if they knew how sex/reproductive cells are produced. Therefore, I also examined students' understanding of the products of meiosis.

Students' Understanding of Products of Meiosis

Item 10 was embedded in activity six of the unit. Table 5.17 below shows Dr. Perry's fifth hour responses to item 10. Item 10 asked students the differences between parent and daughter cells in meiosis. This item was scored on a scale from zero to three because the question did not require that much to be scored up to four. Considering the concepts the students had covered in their unit, students were not expected to provide responses that were beyond comparing number of chromosomes. When I initially scored students' responses, there was a thin line between a score of 3 and 4. As a result, I decided to give a score of a three for a complete response to item 10 (see rubric in Appendix E).

Table 5.17

Examples of Students' Responses to Item 10

Item 10 How is parent cell different from daughter cells in meiosis Ideal response The daughter cell has half the amount of genetic material as the parent cell. The daughter cells has half the number of chromosomes as the parent cell	
Students' Response (KI score)	Comment
Pair 5P1 Parent cells have four chromosomes, while daughter cells have only two chromosomes. Plus daughter cells come from their parent cells and contain their genetic data. (3)	This pair was drawing their evidence from the WISE unit. The example give in the unit had a parent cell with 4 chromosomes and a daughter cell with 2 chromosomes. This pair got a perfect score because they showed understanding of the big idea that there is half of the genetic material in daughter cell as compared to the parent cell.
Pair 5P2 Blank (0)	This pair did not respond to the scaffolding prompt
Pair 5P3 Blank (0)	This pair did not respond to item 10
Pair 5P4 Daughter cells do not have nuclear membrane (1)	This pair believes the daughter cells do not have nuclear membrane. The response show lack of understanding of the differences

Table 5.17 cont'd

	between daughter cells and parents cells in meiosis.
Pair 5P5 The parent cell is different from daughter cell because the daughter has cells that are different because her cells are from both her father and her mother combined (1)	This pair confuses products of meiosis (i.e. sex cells) with offspring. This could probably stem from the use of the words 'parent' and 'daughter' cells
Pair 5P6 It contains half the chromosomes (2)	This pair did not elaborate though they indicate that one has half chromosomes number as compared to the other.
Pair 5P7 Because the daughter cells do not contain 1 new one it makes two. The two daughter cells each contain 2 to make 4. The ones that the daughter cells make are replacements (1)	The response is vague and seem to be confusing mitosis and meiosis
Pair 5P8 The parent cells have one gene and as they reproduce the genes are traded and they duplicate themselves. (1)	The response shows lack of conceptual understanding of the differences between daughter cells and parent cells in meiosis.
Pair 5P9 The parent cell is different from daughter cells because in the parent has only one cell and the daughter has more than cell (1)	This pair does not understand the products of meiosis.
Pair 5P10 Blank (0)	This pair did not respond to item 10.
Pair 5P11 Blank (0)	These students did not respond to this item

The purpose of embedding item 10 in the WISE unit was to make students thinking visible after they interacted with Activity 5 which was 'Looking More Closely at Sexual Reproduction'. This activity had animations and information on meiosis as it pertains to sexual reproduction. Item 10 was designed to enable learners to check on their understanding after going through the activity. Analysis of students' responses to item 10 shows that students have difficulty in articulating the main differences between parent and daughter cells in meiosis. Table 5.18 below shows score frequencies broken down by teacher.

Table 5.18

Score Frequencies of Item 10

Teacher		Score	Frequency	Percent	Valid Percent	Cumulative Percent
Ms Adams	Valid	0	29	39.7	39.7	39.7
		1	2	2.7	2.7	42.5
		2	6	8.2	8.2	50.7
		3	36	49.3	49.3	100.0
		Total	73	100.0	100.0	
Dr. Perry	Valid	0	20	27.8	27.8	27.8
		1	35	48.6	48.6	76.4
		2	9	12.5	12.5	88.9
		3	8	11.1	11.1	100.0
		Total	72	100.0	100.0	

Approximately 40% and 28% in Ms Adams and Dr. Perry's students did not respond to item 10 respectively. As shown in Table 5.18 above, only 11% of Dr. Perry's students had a perfect score of three as measured by the KI rubric. Forty nine percent of Ms. Adams' students had perfect score. However, as mentioned earlier, as from activity four on, Ms. Adams' students who responded to scaffolding support prompts had similar responses. Although I present examples of students' work from one teacher, score frequencies from both teachers are presented. This was because the frequencies help in understanding the importance of teacher scaffolds as they enact web-based curriculum with embedded support prompts. Additionally, the inclusion of score frequencies (including zeros) from both teachers is important in examining students' utilization of scaffolding support prompts designed around a framework that values curricula scaffolds.

Sexual and Asexual Reproduction

Berthelsen (1999) pointed out that a majority of students have difficulty in distinguishing between sexual and asexual reproduction. Embedded in the "From Genotype to Phenotype" curriculum unit were scaffolding prompts asking students to distinguish between sexual and asexual reproduction. In addition, the questions and asked students to list the advantages and disadvantage of each mode of reproduction. Item 21 asked students "What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages?" These questions appeared at after the students had interacted with the concepts about sexual and asexual reproduction. Table 5.19 below shows Dr. Perry's fifth hour students' responses to item 21.

Table 5.19

Examples of Students' Responses to Item 21

Item 21 What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages?
Ideal response Sexual reproduction involves two sex cells, male and female. (Students were given credit for mentioning that in asexual reproduction one parent is involved unlike sexual that involves two). Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents. Sexual reproduction may result in variety of offspring unlike asexual where offspring is a replica of the parent. Asexual

Table 5.19 cont’d

reproduction does not need a mate and usually faster than sexual reproduction	
Students’ response (score)	Comment
Pair 5P1 Asexual reproduction only requires one parent, and the offspring has all of the parent's traits. Sexual reproduction can only occur if there are both a mother and a father. When sexual reproduction occurs, the offspring will receive traits from both parents. (3)	Though they do not highlight the advantages and disadvantages of each, the responses show conceptual understanding of the differences between sexual and asexual reproduction.
Pair 5P2 Blank (0)	This pair did not respond to the item
Pair 5P3 Blank (0)	This pair did not respond to the item
Pair 5P4 Some differences are, in asexual reproduction the offspring only get traits from the one parent. In sexual reproduction the offspring gets traits from both parents. (3)	These students show some understanding about passage of genetic material to offspring in sexual and asexual reproduction though they do not highlight the advantages and disadvantages of each
Pair 5P5 The differences are that in asexual reproduction they take all of their genes from one parent. Basically like a clone because they only have one parent. Sexual reproduction is when the parents combine genes and the offspring receive their genes randomly from the two parents, like the flip of a coin. (3)	This response suggests that the students had understood the main differences between sexual and asexual reproduction though they do not elaborate on the advantages and disadvantages of each
Pair 5P6 Asexual reproductions the offspring is a clone of the parent. This works if there are no males. In sexual reproduction the parents contribute 50 percent of the genes. (3)	These students highlighted the main differences without elaboration on advantages and disadvantages. The mention of ‘no males’ seem to suggest that they believe that it is the females that are involved in asexual reproduction
Pair 5P7 The two boy and girl can make 1, but the asexually way can make them both have 1 of there on (2)	The response is vague and the use of boy and girl could have been examples of male and female in sexually reproducing organisms
Pair 5P8 Asexual is reproduction without a partner and sexual reproduction is the opposite. (2)	This response is not elaborated though it shows some understanding of basics of sexual and asexual reproduction

Table 5.19 cont'd

Pair 5P9 Asexual reproduction is sex with only one parent. Sexual reproduction is sex with two parents. They contribute by making it a different kind of sex. (2)	The responses is vague though its shows some knowledge on number of parents that may be involved in each type of reproduction. The mention of sex may suggest that the pair equates sexual reproduction to copulation
Pair 5P11 Asexual Reproduction involves 1 organism Sexual Reproduction involves 2 organisms (3)	The students show some understanding without elaboration on advantages and disadvantages of each type of reproduction
Pair 5P12 Blank (0)	This pair did not respond to the item

Examination of the responses to item 21 suggests that a majority of the students in this study could make basic distinctions between sexual and asexual reproduction (see for example Figure 5.19 above). However, most students did not respond to the second part of the question that required them to elaborate on the advantages and disadvantages of sexual and asexual reproduction. A sizeable number of students had responses that suggested their equating of sexual reproduction to sexual intercourse. For example, pair 5P9 above had a response supporting the just mentioned claim. It is also important to note that 20.5% of Ms. Adams' students did not respond to the item as compared to 55.6% of Dr. Perry's students. None of Ms. Adams' students scored a one and only two pairs from Dr. Perry's group had a score of one. Students who scored a one could not distinguish between sexual and asexual reproduction. However, only 21.9% (16 pairs) of Ms. Adams' students and 9.7% (7 pairs) of Dr. Perry's students scored a four. As measured by the KI rubric, a four was awarded to students who had complete responses.

Summary of students' conceptions about genetic inheritance

In this subsection, I synthesize students' conceptions about genetic inheritance in relations to the main focus of the WISE unit. As stated earlier, by the end of the WISE unit (developed as part of the larger study) students were expected to have understood concepts elated to Mendel's law of segregation. Understanding of the law of segregation requires students to comprehend that

1. Genes exist in more than one form
2. Organisms inherit 2 alleles for each trait
3. When gametes are formed, allele pairs separate living each cell with a single allele
4. When two alleles are different, one is dominant and the other is recessive.

However, it was evident in students' explanations that some of their out-of-school funds-of-knowledge influenced the kinds of responses they provided – for example, the *resemblance theory* explained above. In figure 5.7 below, I show students conceptions related to their resemblance theory may interfere with their comprehension of Mendel's law of segregation.

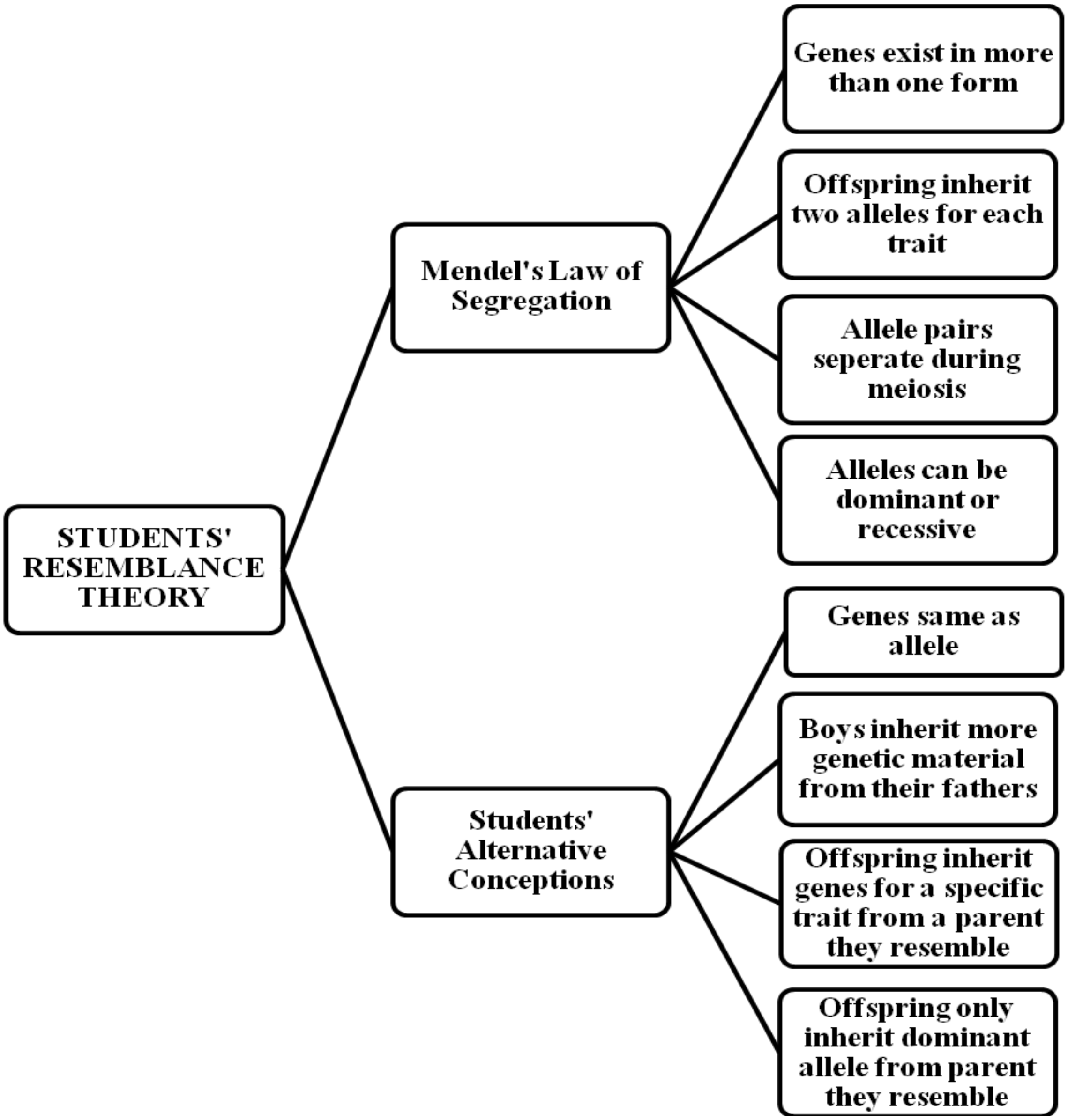


Figure 5.7. Students' *Resemblance Theory* and Mendel's Law of Segregation

For example, the Mendel's law of segregation requires students to understand that genes exist in more than one form yet some students cannot distinguish between a gene and allele. It is in this view that I argue that students' *resemblance theory* as discussed in this study may have an influence on students' understanding about Mendel's law of segregation. Therefore, there is need to have curriculum materials and instructional strategies that challenge students conceptions and build on their resemblance out-of-school funds-of-knowledge. Next, a summary of the findings from this dissertation study is outlined.

Summary of Findings

This study is a slice of a larger study designed to develop students understanding of heredity and related concepts in upper elementary and lower middle school. The larger study promotes students' understanding by embedding scaffolding prompts to support students' learning of genetic inheritance. As part of the larger study, two versions of the curriculum were developed. Version one (claims/evidence unit) had activities that were explicit in helping students know what a claim is and the importance of supporting claims with evidence. Though the biology content was the same, version two (no claims/evidence unit) was not explicit on what a claim is and how to support it with evidence. This study explored seventh grade students' on-line responses to scaffolding support prompts embedded in two WISE curriculum units. Two teachers, Ms Adams and Dr. Perry, participated in this study. Each teacher had five classes of approximately 30 students each giving a total of about 300 study participants. Students worked in pairs as they went through the WISE unit. Therefore each response is attributed to a pair of students. Major findings in this study as follows:

1. There was no significant difference in mean KI scores as measured by the rubric between students who interacted with the claims/evidence WISE curriculum unit and those who interacted with no claims/evidence unit: That is students whose curriculum version was explicit on making scientific claims and supporting such claims with evidence did not provide any better responses to the scaffolding support prompts than their peers who interacted with the no claims/evidence version of the WISE unit. The findings suggest that

the two WISE curriculum versions were equally valuable. Consequently, further analyses done in this study were not stratified by curriculum version.

2. There was a significant difference in KI mean score between students taught by Ms. Adams and those taught by Dr. Perry. Ms Adams' students had a higher mean score. However, these results are confounded by another factor, namely that Ms. Adams' students started having almost the same responses to the scaffolding prompts halfway through the unit, which is from Activity Four through Activity Eight. The results, therefore, cannot be analyzed as being totally reflective of students' thinking. As a result, most of the examples of students' responses were from Dr. Perry's classes.

   Obviously, having Ms. Adams' students have similar responses to the scaffolding support prompts complicates these findings. It suggests that teacher scaffolds may influence the way in which the learners interact with the curriculum scaffolds. There were instances where every student in Ms. Adams' class skipped certain scaffolding support prompts, suggesting the extent of teacher influence in step-by-step guidance through the curriculum unit. The scaffolding support prompts were meant for students to stop and reflect on their learning.

   In sum, the two teachers in this study had completely different styles of facilitating their students learning with the WISE curriculum unit. One teacher allowed the students to go through the unit with minimal guidance, and the other teacher guided students step by step and summarized responses for them for the scaffolding support prompts.

3. I also examined students' understandings of concepts reported in literature as challenging for learners. I found that students drew evidence they used in most of their explanations from their out-of-school experiences. A majority of students attributed their inheritable traits to a specific parent they resembled. For example, if they had the same eye or hair color as their

father, they indicated that they inherited eye or hair color from their father. If they rolled their tongue like one of their parents they indicated that they inherited the trait from that particular parent. It was clear that resemblance of offspring to parents was plausible to students as a relevant explanation about how offspring inherit alleles from parents. Students used their observed resemblances to explain their claims. I call this students' '*resemblance theory'*. Students' resemblance theory may also explain why some students believe that boys inherit more genes from their fathers than they do from their mothers and girls more genes from their mothers than they do from their fathers. That is, students used gender resemblance to explain their claims. Despite students' ability to explain what heredity is, they faced challenges in explaining the relationship between heredity, reproduction and meiosis in sexually reproducing organisms even after interacting with the WISE curriculum unit. The majority of students could not articulate the relationship between DNA, genes, alleles and chromosomes. Understanding of such concepts could help students conceptualize what happens during meiosis and possibly have a more robust understanding of the roles of meiosis and reproduction in genetic inheritance. Although students created hybrid spaces in learning environments, a majority of the students continued to draw their explanations from their lived experiences in the first space and not necessarily from the WISE curriculum unit. However, curricula scaffolding supports are important for knowing what students know which is not typical in traditional instructional practices. WISE curricula scaffolds in this study made it possible to extract students' ideas as they made their thinking visible on genetic inheritance concepts and that has implications for curriculum development.

CHAPTER 6

DISCUSSION

Introduction

In this chapter I revisit my research questions as I discuss the findings of this dissertation study. I highlight my findings and their implications for; 1) the ways in which students' on-line responses, as measured by the Knowledge Integration (KI) rubric, vary (or not) by the type of curriculum version the students received, 2) students' conceptions on genetic inheritance and related concepts, and 3) the ways in which the students' on-line responses vary as a function of their respective teachers. In my view, finding out possible answers to these questions is just as complex as trying to understand what goes on in any science learning environment. There could be many other possible ways of making meaning of the findings discussed in this dissertation study. Therefore my findings could be merely partial explanations to the research questions in this study.

Furthermore, there is not much research that reports on students' responses to curricula scaffolds. Rather most research is on the effect of different types of curricula scaffolds on students understanding of science concepts as measured by their pretest to posttest gains (e.g. Davis & Linn, 2000; Davis, 2003; McNeill & Krajcik, 2006). This dissertation study examines students' responses to on-line curricula scaffolding support prompts.

As previously stated in earlier chapters, this dissertation is part of a larger study that was designed to enhance upper-elementary and early middle school students' learning about genetic inheritance in a Web Based Inquiry Science Environment (WISE). As part of the larger study, two versions of the "From Genotype to Phenotype" curriculum unit were developed. Version one of the unit was explicit on how to make a valid claim and support it with appropriate evidence.

Version two of the unit was not explicit on how to make a claim and use evidence to support it. Both units had scaffolding support prompts that enabled students to make their thinking visible as they interacted with the curriculum unit. Six classes (three per teacher) interacted with the claim/evidence version of the curriculum unit. Four classes (two per teacher) interacted with the no claim/evidence version the unit.

This dissertation study examines students’ responses to scaffolding support prompts embedded in both versions. Using the KI rubric, I explore how students’ responses vary (or not vary) by the version of the unit they received and by the teacher the students had. In addition, I used the hybridity theory to examine the space from which students could have drawn their explanations from as they responded to the scaffolding support prompts.

The Effect of Different Curriculum Version on Students’ KI Scores

According to Sandoval and Kelli (2005), science learning can be viewed as cognitive apprenticeship into scientific practices that are specific for each discipline. Science practices include inquiry and production of artifacts such as models and explanations (Bell & Linn, 2000; Sandoval, 2003; Sandoval & Kelli, 2005). However, science learners do not typically provide robust scientific explanations (McNeill & Krajcik, 2006; Sadler, 2004). Yet making valid claims that are supported by appropriate evidence is one of the common practices in the science community. McNeill and Krajcik (2006) found out that students who received an explicit framework for scientific explanation provided much more complete scientific explanations as compared to students who did not receive such a curriculum. In this dissertation study I was interested in examining whether students who interacted with the unit that was explicit on the use of evidence to support a claim had higher KI scores than those who did not. Using ANCOVA I compared the KI scores of students who interacted with the different versions of the “From Genotype to Phenotype” curriculum unit. My analysis suggests that the students’ KI scores for their on-line responses did not vary by the type of curriculum unit the students received. In this study, students who interacted with the curriculum unit that was explicit on the use of evidence to support a claim did not provide scientific explanations that were any better than those of students who received the curriculum version that was not explicit on the use of evidence. There are a couple of possible explanations why these findings are contrary to work done by other researchers (for example McNeill and Krajcik (2006).

First, maybe the students who interacted with claim/evidence did not have enough experiences of learning about making valid claims and supporting them with appropriate evidence. This could mean that the claim and evidence learning experiences within the “From Genotype to Phenotype” may not have been sufficient to result in significant differences on students’ explanations to scaffolding support prompts embedded in the two versions. Given the idea that scientific explanations are a central artifact of science (Sandoval & Kelli, 2005), it is important to afford students enough learning experiences about their construction. In the “From Genotype to Phenotype” claim/evidence curriculum version, students had one activity (out of eight) that explicitly afforded students experiences of learning about making claims and supporting them with appropriate evidence. The claim/evidence version had three other activities that had sentence starters to remind students to make a claim and support it with appropriate evidence. In my view, one activity framed around use of evidence and simply occasionally prompting students to make a claim and support it with evidence may not provide enough learning experiences to support students’ construction of scientific explanations. I argue that in a curriculum unit framed around use of evidence to support claims, students need more students’ experiences in learning about valid claims and appropriate evidence. Most if not all of the activities should have been framed around construction of scientific explanations that is valid claims supported by appropriate evidence. Furthermore, I argue that in the claim/evidence version of the unit, the general framework of explicitly helping students understand how to support their claims with appropriate evidence should have remained constant throughout the project (e.g. McNeill & Kracjik, 2006). McNeill and Kracjik (2006) highlighted the importance of having the curriculum design framework evident throughout the curriculum unit. This view suggests that most of the activities in the version one of the "From Genotype and Phenotype" curriculum unit should have been framed around the design framework, which was supporting students in making valid claims and supporting them with appropriate evidence. Thus continued learning support could have been important in providing students with sufficient experiences to learn about the design framework (McNeill & Kracjik, 2006). Maybe having one activity (out of eight) was not enough experiences with the claim/evidence framework. However, this may not be the only possible reason of why students who interacted with claim/evidence unit did not provide explanations that were any better than their peers who received a no claim/evidence unit.

Second, it is possible that some of the embedded scaffolding support prompts may not have been knowledge integration questions that required students to make valid claims and support them with appropriate evidence. Gotwals and Songer (2009) highlighted the importance of assessment in understanding what students know. These authors further argued that assessment process includes gathering evidence about students' knowledge as well as making interpretations about what students know. This view suggests the importance appropriate assessments tools in gathering evidence about students' knowledge. As a result, assessment items should measure the knowledge they are supposed to measure so that appropriate inferences about students' knowledge are made. It is possible that some of the embedded assessment items may have been phrased in ways that did not require students to provide evidence; or perceived by students as not requiring evidence. Either way, students may end up providing less robust scientific responses. This dissertation study is not about validity and reliability of the scaffolding support prompts that were embedded in curriculum. Rather, my study examines students' responses to the embedded prompts. I am not claiming that some of the items may not have been phrased in ways that require use of evidence. I am arguing that it is possible that some assessment items may be perceived differently by students such that they may not provide complete explanations.

Third, the ways in which the students interact with the curriculum and the embedded scaffolding prompts may influence the efficacy of curriculum supports. As pointed out by Chinn, (2006), "questioning is used to diagnose and extend students' ideas and to scaffold students' thinking" (p. 1319). This view suggests that students' responses may be used to broaden their thinking in ways that extend students learning and knowledge. Consequently, the ways teachers make use of the students' responses to embedded scaffolding support items may enhance or undermine the scaffolding support design principles. Besides the curricula scaffolds, teachers naturally provide their students with supports as they learn. McNeill and Kracjik (2006) argued that during curricula enactments, teachers provide supports that enable students learn about the general framework. This view suggests that teachers understanding of the curriculum design principles coupled with their enactment of the unit may possibly influence students learning about the design and science concepts.

In this study the curriculum design framework was centered on supporting students construct valid scientific claims that are supported with appropriate evidence. Teachers are generally responsible for supporting students in constructing scientific explanations. However, it is possible that the teachers in this study may not have provided appropriate and sufficient supports to enable the students to understand the claim and evidence framework. In other words, curriculum implementation may have influenced students learning about the claim/evidence as it relates to genetic inheritance concepts as measured by the KI scores in this study. It is also possible that the teacher participants in this study did not have complete understanding of the principles behind the curriculum design. Such understanding might have enabled them to give their students sufficient guidance. The possible explanations to the study outcome I have just discussed leads me to the discussion on ways in which the students' on-line responses varied as a function of their respective teachers.

Teacher Effect on Students' Knowledge Integration Scores

McNeill and Krajcik (2008) argued that science education field should go beyond acknowledging the role of teachers; rather their roles need to be known so as to provide appropriate support to them in creating inquiry environments. Furthermore, there is not much research that describes teacher's instructional roles in enacting inquiry based curriculum such as WISE (see for example Bell & Linn, 2000; McNeill & Krajcik, 2009; Sandoval, 2003). Therefore the identification of some of the teachers' ways of guiding their students through a web-based inquiry environment might add onto the academic discussion on the role of teachers in enacting inquiry based units with curricula scaffolds.

In this dissertation study, ANCOVA analysis suggests that there was a significant difference in students' knowledge integration scores between students taught by the two teachers. Ms. Adams' students had significantly higher KI scores than Dr. Perry's students.

Though this quantitative analysis may suggest that Ms. Adams' students showed better conceptual understanding of genetic inheritance as revealed by their KI scores, my qualitative analysis of some of the students' responses did not reveal that. Qualitative analysis of the responses showed that the differences in KI scores between students taught by Ms. Adams and Dr. Perry may be explained by the disparities in which their students utilized the scaffolding supports in addition to different instructional approaches the two teachers employed to scaffold their students' use of the embedded prompts.

Although, this dissertation study is not about the teachers' instructional practices, there were some observed instructional patterns that may be used to partially explain the findings. Dr. Perry and Ms. Adams implemented the curriculum in somewhat different ways. The results presented in Chapter Four of this dissertation study showed how Dr. Perry might have allowed students to go through the unit at their own pace. That was not the case with Ms. Adams whose classroom observations and students' work suggest that she had the whole class go through the unit at the same pace. However, Ms. Adams' students started having similar responses from Activity Four on. Similar responses clearly demonstrated the type of support Ms. Adams provided for her students as they interacted with the curricula scaffolds. Although Ms. Adams' students ended up having greater KI scores than Dr. Perry's students, their scores from activity four on could not be attributed to students' independent thinking and understanding about genetic inheritance. Hence the significant score differences revealed by ANCOVA may be a result of the differences in the types of teacher scaffolding supports the students received. However, it is important to note that prior to activity four, students in both teachers' classes had similar pattern of responses. As from Activity four, Ms. Adams extended her scaffolds from step by step guide through the curricula activities to discussing the model responses to curricula scaffolds possibly resulting in her students having a higher mean score as compared to Dr. Perry'.

Nonetheless, it is also important to note that prior to enactment of the "From Genotype to Phenotype" curriculum, the two teachers indicated (in a questionnaire that was part of the larger project) their comfort levels of using instructional technology. Ms. Adams indicated that though she was confident in teaching science, she was not at all confident in using computer-based instructional technology. Dr. Perry pointed out that he was very confident in teaching science and was somewhat confident with instructional technology. It is possible that the teachers' comfort levels in using educational technology coupled with their pedagogical beliefs may have influenced the ways they provided scaffolding supports to their students.

Research has shown that teacher's teaching philosophy; pedagogical beliefs and openness to change are highly associated with how a teacher uses educational technology with their students (e.g. Vannatta & Fordham, 2004; Hernandez-Ramos, 2005; Judson, 2006). This view suggests that teachers enact technology based curriculum in ways that are compatible with their pedagogical orientation they believe will enable them to accomplish their instructional goals (Windschitl & Salh, 2002; Zhao, Pugh, Sheldon & Byers, 2002). It is in this view that I argue that teachers in this study might have been influenced by their beliefs on what constitutes good teaching in enacting the "From Genotype to Phenotype" curriculum unit. As a result, whatever supports the teachers provided to their students could have been largely driven by their own teaching philosophies. However, it is possible that the teachers in this dissertation study may have created '*hybrid instructional practices'* that combines their own 'traditional instructional practices' and the 'web-based instructional' platform. Traditional instructional practice in this instance refers to the teaching practices the teachers were used to considering that they both indicated that they rarely used web-based curriculum. The compatibility of the teachers' traditional instructional practice and the web-based instructional platform may result in hybrid instructional practices that, in my view, may result in three possible scenarios. The scenarios can be at different levels, for example level one through level three.

First, the *hybrid instructional practice* level one may be a result of the amalgamation of teacher's traditional instructional practices (that may be incompatible with instructional technology demands) and a web-based curriculum platform. Such incompatibility may results in creation of level one *hybrid instructional practice* that may possibly result in insufficient or inappropriate strategies that might not enable students to understand the claim and evidence framework for scientific explanations. For example, scaffolds were meant to make students' thinking visible and reflect on their learning as they construct new knowledge webs. However, having students produce similar responses obviously complicated the perceived benefits of the curricula scaffolds.

Second, the *hybrid instructional practice* level two may be instances where there is partial compatibility between the teacher's traditional instructional practices and the web-based curriculum instructional demands. It is possible that partial compatibility may result in a *hybrid instructional practice* that does not adequately support students to learn about the framework; in this case making claims and supporting them with appropriate evidence. For example, a teacher may not provide the students with adequate instructional support though the practice may encourage independent thinking. In such instances, both the teacher and the students may end up under utilizing the scaffolding support prompts. In the "From Genotype to Phenotype" there were a couple of scaffolding supports that were repeated. The majority of students in this study did not respond to the items that were embedded more than once in the curriculum. It is possible that students may have viewed repeated scaffolding prompts as redundant since they addressed the same need or learning goals (McNeill & Krajcik, 2009; Tabak, 2004). In my view, the teachers should have browsed the responses and diagnose students misconceptions, then encourage them to respond to the repeated questions. That way, it would have been possible to utilize curricula scaffolds in ways that extend students' thinking and learning.

Third, the *hybrid instructional practices* level three may be the kind of practice that results from the fusion of highly compatible teacher's traditional practices and the web-based technology platform. Consequently, teachers who create *hybrid instructional practices* in level three would possible provide appropriate and sufficient scaffolds to their students. The students who receive such instruction may show adequate learning about genetic inheritance concepts in addition to appropriate understanding of the claim evidence framework. If teachers have instructional practices that are highly compatible with the web-based curriculum, it may be possible to have a majority of students who interacted with the claim/evidence unit have significantly higher KI scores than their peers who received a unit that was not explicit on claims and evidence.

Nevertheless, examination of curricula scaffolds in this dissertation provided a rare opportunity of examining students' conceptions as they interacted with the unit which is a rare opportunity in learning environments that do not have scaffolding support prompts. Next, I discuss some of the students' conceptions on genetic inheritance as reflected in their responses to scaffolding supports.

Students' Conceptions on Genetic Inheritance and Related Concepts

Research has shown that regardless of the importance of genetics in the modern world, genetic inheritance concepts remain the most challenging concepts to teach and learn, from both linguistic and conceptual view points (Tsui & Treagust, 2007; Stewart, 1982; Venville & Treagust, 1998). Furthermore, AAAS (2001) highlighted the importance for students to have a good understanding of the reproduction process and of cell growth and development in order for them to develop a coherent understanding of heredity (Lewis, Leach, & Wood-Robinson, 2000; Williams et al. 2010). However, research on students understanding of genetic inheritance reveal that many students lack insights into the invisible processes that link organisms' genotypes to their phenotypes even after instruction (Banet & Ayuso, 2000; Kara & Yesilyurt, 2008; Lewis & Wood-Robinson 2000; Slack & Stewart, 1990; Wood-Robinson, 1994).

As discussed earlier, students draw ideas regarding genetic inheritance from different sources including home, peers, movies and electronic games (Nelkin & Lindee, 2004; Venville, Gribble & Donovan, 2005). It is important to note that some of the aforementioned sources do not portray the genetic information in the same way that it is understood in the scientific world. For example, some electronic games that have characters that have DNA and the characters are also capable of "DNA dig-evolving" that involves elevating the character to higher and more powerful levels (Nelkin & Lindee, 2004; Venville, Gribble & Donovan, 2005). The changing of an organism's DNA to make it a higher and more powerful character does not portray how DNA as it is understood in the scientific world. As a result, students have diverse funds of knowledge sources some of which may compete with the scientific world and its discourse. The hybridity theory can apply to the integration of competing and non competing knowledge and discourses (Moje at. al., 2004). In this section I discuss students' conceptions about genetic inheritance as reflected in some of their online responses to the scaffolding support prompts. It is important to note that unlike in pre and post assessments, students in this study had opportunities to revisit their earlier claims and edit or revisit the text if they wanted to check on their own responses. When I was scoring the students' responses, not only was I interested in their scientifically correct responses and frequencies of complete responses, I was also interested in their understanding and ideas about genetic inheritance. Next I discuss some of the students' ideas about genetic inheritance.

Passing Genetic Material from Parents to Offspring

Research has shown that some students have difficulty in comprehending the passage of genetic material from parents to offspring (e.g. Banet & Ayuso, 2000; Kargbo et al., 1980; Lewis & Kattmann, 2004). Embedded in the "From Genotype to Phenotype" curriculum units were scaffolding support prompts that solicited students' knowledge on concepts that had been identified as challenging for some learners. For example, literature says some students believe boys inherit more from their fathers than their mothers (Kargbo et al., 1980). Kargbo and his colleagues found out that most students believe that one parent contributes genes for some characteristics and the other parent contributes genes for other features. This is consistent with the findings in this dissertation study. Some students attributed certain traits to a specific parent as if it was the only parent that passed on to them the alleles for certain traits and not others. These students seem to believe that for each inheritable trait, they inherited it from the parent they resemble. As pointed out by Moje et al. (2004) students get their information from a variety of spaces that include out-of-school funds of knowledge. Students observe resemblance in family members and they were using their out of school observations to explain their responses. In other words, some students continued to draw their explanations and evidence to support their claims from their first space that is their out of school funds of knowledge.

Students' ideas of attributing traits to specific parents can also be used to explain their conceptions on boys (or girls) inheriting more genes from their fathers (or mothers) that their mothers (or fathers). This can be explained by the students' *resemblance theory* and it is possible that students will be basing their explanations on the idea of gender resemblance. It is in this view that in this dissertation study I argue that the students understanding of parental resemblance can be used to explain students' beliefs that one parent contributes genes for some characteristics and the other parent contributes genes for other features. There are a couple of possible reasons why students in this study attributed certain features to a specific parent.

First, it is possible that the ways in which the scaffoldings support prompts that had the word "trait" might have been perceived by students differently. It is possible that some students could have given similar of different responses if the word "traits" was replaced with "genes' in the following questions; What are some traits you inherited form parents? Is it true of false that boys inherit more traits from their fathers than their mothers? In this study, trait is defined as a feature that can be inherited from parents or a characteristic that can be acquired from the environment. When students were asked about the "traits they inherited from their parent", it is possible that they were merely listing inheritable traits and mention the parent they resemble as evidence to support their claim.

Second, attributing traits to a specific parent may suggest that students had isolated ideas about the process of inheriting alleles from parents. This explanation is consistent with literature that says a majority of students believe that one parent contributes genes for some characteristics and the other parent contributes genes for other features (e.g. Karbgo, et al. 1980). Students who attribute traits to a specific parent may believe that they only got genes for a certain feature from only the parent they resemble for that trait. This view suggests students' lack of understanding of how alleles are passed on from parents to offspring.

Students who believe that one parent contributes to offspring genes for certain features and the other parents contributes genes for the other features show lack of coherent understanding on how genetic material is passed from parents to offspring. In their explanations, some students pointed out that it was the 'dominant gene' that is passed from parents to offspring. It is possible that students with such responses may believe that only dominant and not recessive alleles are passed on from parents to offspring. In other words, it is likely that those students may believe that they inherited only dominant alleles and only from the parents they resemble for each inheritable trait. That belief suggests students lack understanding about dominant and recessive alleles and how they are passed on from parents to offspring. Additionally, students may be lacking knowledge that chromosomes are in pairs (that is homologous chromosomes) with one from each parent. As a result, some students may fail to comprehend that alleles are also in pairs and one of the pair is found in each homologous chromosome. Related to these concepts is the understanding of meiotic division that results in daughter cells (sex cells) with half genetic material; in addition to knowledge about the union of male and female sex cells in producing offspring with full set of chromosomes.

It is possible that students' *resemblance theory* (which is predominantly first space funds of knowledge) may have some predictive power on students understanding about how offspring inherit genetic information from parents. This means that students' understanding about parental resemblance may influence the way they create hybrid spaces as they interact with school curricula. Consequently, learning environments need to have activities that challenge students' out-of-school competing and non-competing funds of knowledge that may (or may not) interfere with knowledge integration and recreation of new knowledge as they integrate different funds of knowledge in hybrid spaces. Moje et al. (2004) argued that because science is a highly specialized area with a lot of assumptions about what counts as scientific knowledge, the idea of integrating in and out-of-school funds of knowledge becomes challenging. In this dissertation study I argue that learning environments that challenge or build on students' *resemblance theory* may enable students to make connections between their first space (out-of-school) and second space (in-school) funds of knowledge. That way, students may be able to integrate their in and out-of-school funds of knowledge and create scientifically robust hybrid spaces. However, McNeill and Krajcik (2009) argued that learning environments need to do more than just mentioning the similarities of out-of-school students' ideas and school science. These authors pointed out the importance of discussing with students both similarities and differences between out-of-school and school science so as to possibly enhance students' coherent understanding of concepts taught in school. Related to students' *resemblance theory,* is students' understanding about the relationship between gene, allele, genotype and phenotype.

Students Conceptions about Relationship between Alleles, Genes, Genotype and Phenotype

It is possible that students' beliefs that they inherit genes for specific traits from a specific parent (e.g. Kargbo et. al., 1980) may influence their understanding of the relationship between alleles, genes, genotype and phenotype. Furthermore, students' difficulty in comprehending how they inherit alleles for a trait from both parents may emanate from their *resemblance theory* coupled with lack of understanding about cell division and reproduction.

Alleles, genes and genotypes involve structures that cannot be seen by a naked eye. It is important for students to understand that a gene is simply basic instruction or sequence of DNA whereas an allele is a variation of that instruction. Inherited characteristics are determined by specific genes and most genes have two or more variations called alleles. Analysis of the students' responses suggests that they had difficulty in distinguishing between a gene and an allele (Lewis & Wood-Robinson, 2000). Though learners in this study could define genotype, majority of them could not explain the relationship between alleles, genotype and phenotype.

The findings in this study are consistence with literature on students' beliefs that one parent contributes genes for some characteristics and the other parent contributes genes for other features (e.g. Kargbo et al. 1980). This finding is consistent with research in the field (e.g. Lewis & Wood-Robinson, 2000) that points to students' difficulty in understanding genetic contributions from parents to offspring. The just mentioned belief is likely to have some predictive power on students' understanding of the relationship between alleles, genes, chromosomes, genotypes and phenotype. As discussed earlier, in my view such a belief can be explained by students' resemblance theory. If students believe that one parent contributes genes for some characteristics and the other parent contributes genes for other features it shows that they may be lacking coherent understanding on the relationship between alleles, genes, DNA, chromosomes and how genetic information is passed from parents to offspring. In addition, some students showed that they did not understand the process of meiosis. Meiosis results in sex cells that have half genetic material. It can be inferred that students who lack conceptual understanding of meiosis may also fail to comprehend how genetic information is passed from both parents to an offspring.

CHAPTER 7

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATION

Introduction

This chapter highlights the conclusions drawn from the study, implications and recommendations. This study contributes towards scholarly discussions on curricula scaffolds, influence of teacher supports on students' use of curricula scaffolding prompts and students conceptions on genetic inheritance. This dissertation study found out that the way students used curricula scaffolding support prompts in addition to teachers' classroom facilitation could influence students' learning about making scientific explanations. Furthermore, under-utilization of the scaffolding support prompts compromises the curriculum design principles that put emphasis on curricula scaffolds to support students learning.

Conclusions, Implications and Recommendation

Students learning and understanding of abstract concepts such as genetic inheritance may be influenced by many interrelated factors. As discussed above, these factors may include (but not limited to) the extent to which the curriculum design and framework enables students' knowledge integration, the ways in which the teachers enact the curriculum and the manner in which the students utilize the curriculum.

In this section, I highlight some of the implications and recommendations based on the findings in this dissertation study. This study contributes towards the scholarly conversations in three main areas. These scholarly conversations include discourse about curricula scaffolds, students' knowledge integration in hybrid spaces and students conceptions about genetic inheritance. Therefore, I discuss the implications, limitations and recommendations in each of these three areas.

Curricular scaffolding supports. This study contributes towards the conversations about online curricula scaffolding support prompts. Previous studies (e.g. Davis & Linn, 2000; Davis, 2003; McNeill & Krajcik, 2009) have documented the importance of different types (such as self monitoring, generic, claim/evidence) and levels (e.g. continuous versus fading) of curricula scaffolds. Although previous studies have identified types and levels of scaffolds that may enable students learning as measured by pretest to posttest gains, there has not been much work done on the nature of the curricula scaffolds and how students use them. My dissertation study shades some light on students' use of on-line curricula scaffolding support prompts.

Although classroom scaffolds have been traditionally defined as the interaction between teacher and student, such one-on-one supports may not be feasible in large classes (Hogan & Pressley, 1997). McNeill, Lizotte, Krajcik and Marx (2006) argued that when teachers interact with the whole class, they encounter multiple zones of proximal development thereby limiting the possible successes of teacher-students scaffolding supports. Instructional materials with embedded scaffolding supports has been the subject of investigation to possible solve problems of lack of one-on-one support in classrooms.

Students' utilization of the scaffolding support prompts in this study raised a number of issues with regard to their perceived benefits. For example, some students were not responding to the prompts thereby undermining the design principles that value curricula scaffolding supports. Having students not responding may also be a reflection of how teachers enacted the curriculum unit. It is possible that the issues with utilization of scaffolding supports may be a result of both students and teachers' lack of understanding of the curriculum design framework. This study did not gather evidence on students and teachers' understanding of the design framework. In other words, there is no evidence on whether the participants knew about the role of the scaffolding support prompts that were embedded in the curriculum unit. Therefore, this study can only infer from the manner in which the prompts were utilized that maybe the participants needed more support in understanding the design framework behind the unit. It is possible that the professional development (that was part of the larger study) may not have sufficient for teachers to understand the design framework in-order for them to provide appropriate guidance to their students. This study recommends that the teachers need more support and guidance on the design framework for them to be able to enable their students to understand the framework. However, this study did not solicit the participants' views with regards to the design framework. This was one of the weaknesses of this study. More work is needed that gathers more evidence on students and teachers' views on curricula scaffolding support prompts.

Students' conceptions about genetic inheritance. This dissertation study contributes towards literature on students' conceptions about genetic inheritance and how some of their conceptions may influence their understanding of scientific concepts. One important aspect about students' out-of-school funds of knowledge that may impact their knowledge integration may be students' "*resemblance theory*". It is possible that it is from this theory that students start to develop their conceptions about genetic inheritance. This study recommends that curriculum that builds on students' prior knowledge about genetic inheritance may need to consider activities that challenge students' *resemblance theory*. However, more research is needed that gathers students thinking about the resemblance. Such studies need to consider probing students to explain their reasoning possibly in the form of think aloud interviews.

It was evident in some of the students' explanations that when they create on-line hybrid spaces, they continue to draw from the out-of-school experiences. For example, the resemblance of parents to offspring is possibly and out-of-school observation and experience. More research work is needed that identifies the predictive power of some the students' out-of-school funds of knowledge. In other words, not much is known about how some of the students' out-of-school funds of knowledge may enable or hinder students' coherent understanding about genetic inheritance.

This study contributes toward literature on students' knowledge integration in a hybrid space. It was evident in some students' responses that they support their claims using their out-of-school funds of knowledge even as they build on their prior knowledge. Figure 7.1 below depicts how '*students' resemblance theory'* (an out-of-school funds-of-knowledge) may influence students creation of third spaces as they integrate their knowledge.

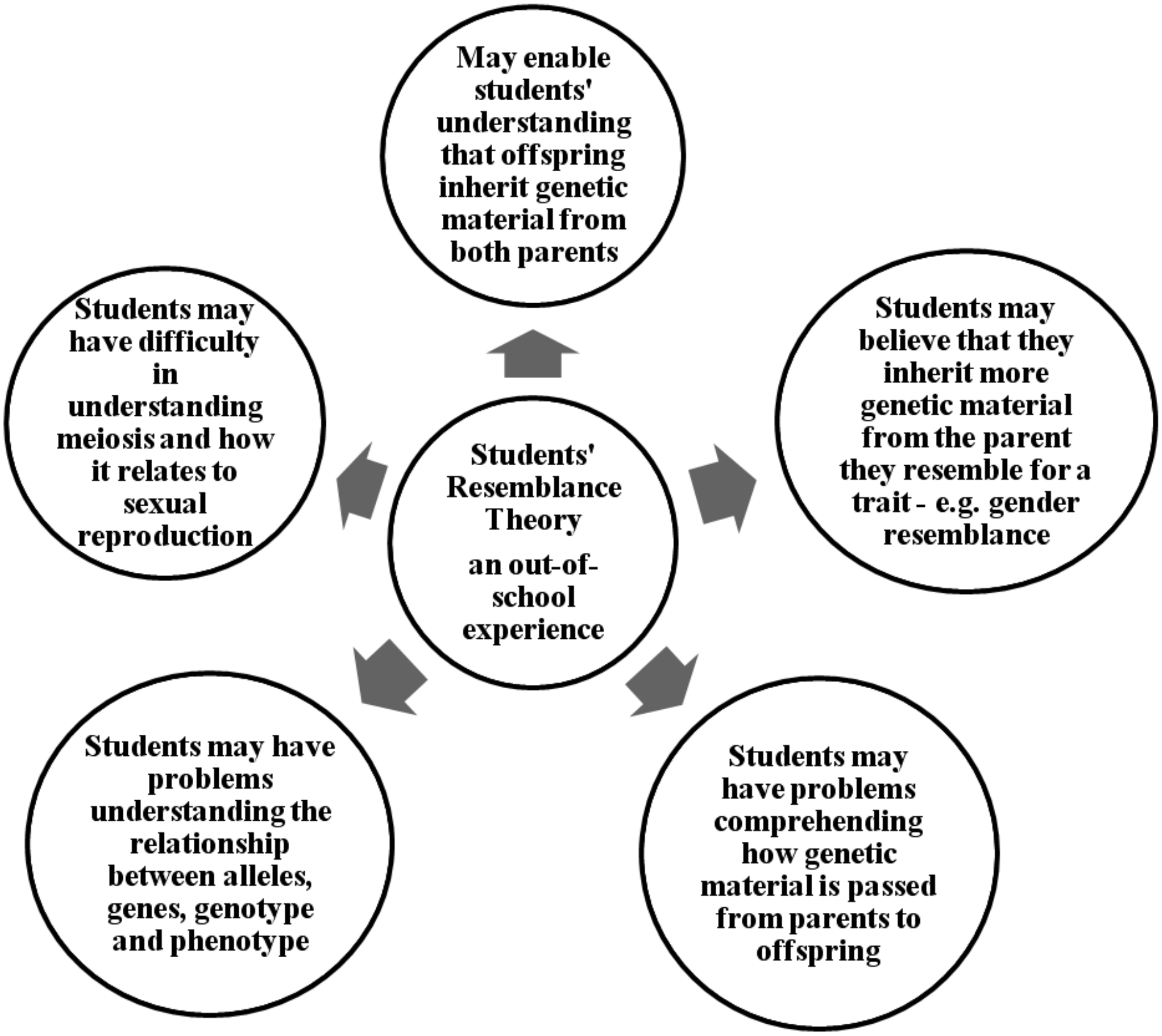


*Figure 7.1.*Students' Resemblance Theory and Conceptions

From this study, it can be inferred and concluded that students' *resemblance theory* could have an influence on students' learning and understanding about genetic inheritance. For example, students' *resemblance theory* (an out of school experience or observation) may enable them to understand that offspring inherit genetic material from both parents (e.g. Figure 7.1 above). In addition, *resemblance theory* could partially explain students' conceptions in some of the following areas:

1. Some students believe that boys (of girls) inherit more genetic material from their fathers (or mothers) than their mothers (or fathers). In my view, it is possible that such beliefs are most likely to have emanated from students' observations based on gender resemblance reasoning.
2. Some students believe that offspring inherit genes for specific features from a parent they resemble. It is possible that students who have such beliefs do acknowledge that they inherit genetic material from both parents but they fail to understand that for each feature, they get an allele from each parent – and that the expression depends on whether the alleles are recessive or dominant. This may result in students having a difficulty in understanding how genetic material is passed from parents to offspring.
3. It is possible that students who believe that they inherited genes for specific features from a parent they resemble for that feature may find it more challenging to understand the process of meiosis and its role in reproduction. That may also lead to students having challenges in understanding the relationship between genotype and phenotype.

Recommendations for Future Studies

There is need to do more work on the following:

1. There is need to do more work on the role of professional development that enable teachers to enact modules that may not be aligned to their own traditional practices. It is important to understand the kinds and levels of teacher support that give them enough experience that enable them to enact new innovations in ways that do not undermine the design principles behind the enacted modules.

2. It is possible that there are some students' out-of-school funds of knowledge that may influence their learning about genetic inheritance. This study identified '*students' resemblance theory'* as a possible out-of-school experience that may impact students understanding. Therefore, more work is needed on students' thinking around issues of resemblance. Students' 'think-aloud' may strengthen the field' by providing learners' reasoning behind resemblance. Furthermore, more research is needed on the possible influence of *students' resemblance theory* on their understanding of Mendel's law of segregation.

APPENDICES

Appendix A

Curriculum Covered by the students

Table 3.3

Curriculum Covered by the students

Activity	Steps	Description
ACTIVITY 1 Will You Help Us Solve a Mystery?	Introduction	Introduces the curriculum unit and heredity in general
	Fast Plants Mystery	Introduces students to the over-arching question that will lead them through the project
	Thinking About Our Mystery	Asks students to speculate on how learning about heredity will help them to solve the Fast Plants mystery
	What Are Fast Plants?	Gives students a brief overview of the history of Fast Plants and their use in the classroom
ACTIVITY 2 Inherited and Acquired Traits	Introduction to Traits	Introduces the idea of “traits” as characteristics
	What I know	Solicits students’ prior knowledge on traits
	Let’s Talk About Traits!	Describes and gives examples of inherited and acquired traits
	Reviewing Traits	Assesses students’ understanding of inheritance of traits
	Sorting Activity	Students distinguish between inherited and acquired traits by dragging and dropping ‘traits’ into appropriate categories
	Thinking About Our Mystery	Students to identify which of their Fast Plants’ traits are inherited and which are acquired
	Traits for Survival	Students think about traits not only as distinguishing features but also as traits that enable organisms survive in their respective environments
	Adaptations Quiz	Students take an interactive quiz from “EcoKids” on animals that have adapted to survive in an arctic environment
	Check-point	Assesses students’ knowledge on what they covered
ACTIVITY 3 Cell Structure and Function	Basic Units of Life	Introduces the students to the idea of cells as building blocks and that all living things are made up of cells
	Structure of a Cell	Allows students to explore animations depicting a plant cell and an animal cell
	Animal or Plant?	Checks students’ understanding of the difference between a plant and an animal cell
	Notes to a Sixth Grader	Students explain certain concepts to a sixth grader, including what cells are and what their functions are
	Cell Doctor	In-class activity in which they act as a “cell doctor” and “heal” numerous organelles, in the process naming that organelle and identifying its function

Table 3.3 cont'd

	Reflections on Cell Doctor Activity	Checks students' learning from the in-class Cell Doctor activity
	Chromosomes and DNA – What's the Deal?	Defines "DNA" and "chromosome" for students, and provides a visual representation of these concepts
	Genes and Alleles	Defines "gene" and "allele" for students, and provides a visual representation of these concepts
	A Recipe for Traits	Students will do an in-class activity in which they receive "genes" for several of a dog's traits, then put those "genes" together to make a strand of "DNA," interpret what the "alleles" are coding for, and draw a dog with these traits
	Discussion on A Recipe for Traits	Students make their thinking visible by participating in an on-line discussion with their classmates about the diversity of the dogs created in the previous activity
	Thinking About Our Mystery	Students reflect on how the concepts in this Activity will help them solve the Fast Plant
ACTIVITY 4 Cell Growth and Division	Introduction to Cell Growth and Division	Describes mitosis as the method that most cells use to reproduce
	Cell Reproduction: Mitosis	Explains the importance of mitosis
	Interphase	Introduces and describes interphase visualization
	Phases of Cell Division	Students see animation of mitosis happening and are asked to break it into five phases
	Scientists Agree	Shows students the five generally accepted phases of mitosis using visualization
	Differences in the Phases	Students make their thinking visible by describing the differences between the five stages of mitosis
	Mitosis Illustration	Students are shown two visual representations of mitosis (one static, one animated), with emphasis placed on the number of chromosomes in the parent and daughter cells
	The Process of Mitosis	Students are shown another animated representation of mitosis, then asked to do an in-class activity in which they act out the process of mitosis
	Reflections on Acting Out Mitosis	Asks students to reflect on how their part in acting out mitosis fit into the bigger process

Table 3.3 cont'd

	Why Mitosis?	Checks students understanding of concepts regarding the role of mitosis
	Thinking About Our Mystery	Students make their thinking visible by reflecting on how the concepts in this Activity will help them solve the Fast Plant mystery and by identifying the information that they still need
	Microscope Activity	Placeholder step – at this chronological point in the unit, students will do an in-class activity in which they use microscopes to view cells that are undergoing mitosis
ACTIVITY 5 Cell Differentiation	Introduction to Multi-Cellular Organisms	Introduces students to the concepts of multi-cellular and single-celled organisms, and places the focus for the Activity (and for the entire unit) on multi-cellular organisms
	Cell Differentiation	Explains that in a multi-cellular organism, cells are specialized to perform certain functions
	Organization of Cells	Describes the hierarchy of cells, tissues, organs, organ systems, and organisms
	Different Kinds of Cells	Explains that cells can divide at different rates, then provides several examples of different types of cells using the TELS visualization and asks students to think about their different functions and how that influences their rate of division
	Notes to a Sixth Grader	Makes students' thinking visible by asking them to explain to a sixth grader why different cells divide at different rates
	Frequency of Division Exercise	Uses a TELS interactive visualization to ask students to place the types of cells (introduced two steps back) in order based on how often they divide
	Reflections on Frequency of Division Exercise	Makes students' thinking visible by asking them to explain the reasoning they used in the previous step
	Thinking About Our Mystery	Students make their thinking visible by reflecting on how the concepts in this Activity will help them solve the Fast Plant mystery and by identifying the information that they still need
ACTIVITY 6 Sexual Reproduction and Meiosis	Introduction	Describes sexual reproduction as reproduction involving two parents
	What is Sexual Reproduction?	Explains sexual reproduction more technically, in terms of gametes and fertilization, and points to pollination as an example of sexual reproduction that the students should be familiar with

Table 3.3 cont'd

	Thinking About Our Mystery – Sexual or Asexual?	Makes students' thinking visible by asking them to explain whether their Fast Plants reproduce sexually or asexually
	What is Meiosis?	Introduces and describes the process of meiosis, and allows students to watch several videos depicting the process by way of a step adapted from TELS
	Meiosis Illustration	Reminds students of the mitosis illustration shown in the similarly-named step from two Activities back and asks them to compare and contrast, again with special emphasis placed on the number of chromosomes in the parent and daughter cells
	Mitosis vs. Meiosis	Makes students' thinking visible by asking them to contrast the two processes and reflect on reasons for the differences
	The Father of Modern Genetics	Describes Gregor Mendel and his work with pea plants
	Mendel's Genes	Explains the concepts of dominant and recessive alleles and Punnett squares, and includes a visual of a Punnett square
	Rose Family Predictions	Makes students' thinking visible by asking them to use Punnett squares to determine the genotypes of two generations of roses, focusing on flower color
	Reflections on Rose Family Predictions	Makes students' thinking visible by asking them to reflect on why the Rose Family Predictions activity turned out the way it did (that is, the recessive white flower color skipped a generation)
	Reproduction in Frogs	Provides a brief description of a frog's life cycle, since students will be using the reproductive cycle of frogs as an in-class example of an organ system in animals
	Notes to a Sixth Grader – Homework Help	Makes students' thinking visible by asking them to explain several concepts to a sixth grader, including the relationship between genes and chromosomes and the inheritance of recessive traits from heterozygous parents
	Inheriting Disease!	Describes cystic fibrosis, and triggers students' thinking about propensity of inheriting diseases in similar ways that they inherit other traits
	Cracking the Code	Students watch a video from NOVA on a child with Tay-Sachs disease and are introduced the idea of testing for inherited diseases

Table 3.3 cont'd

	Talking About Inherited Diseases	Students engage in an on-line discussion with their classmates about testing for inherited diseases, which stimulates students' thinking about the moral and ethical issues that can be raised by inherited diseases
	Thinking About Our Mystery	Students make their thinking visible by reflecting on how the concepts in this Activity will help them solve the Fast Plant mystery and by identifying the information that they still need
ACTIVITY 7 Sexual and Asexual Reproduction	Activity Introduction	Instructs students to focus on asexual reproduction
	Sexual and Asexual Reproduction: Advantages and Disadvantages	Contrasts sexual and asexual reproduction and describes various advantages and disadvantages of each
	Reflections on Reproduction	Makes students' thinking visible by asking them to describe circumstances each type of reproduction would be beneficial
	Sea Monkey Activity	CS-created interactive animation in which students get to decide the traits of two sea monkeys, which can reproduce sexually or asexually, and then get to create offspring from one or two parents (that is, asexually or sexually)
	Reflections on Sea Monkey Activity	Makes students' thinking visible by asking them to reflect dominant and recessive traits and to contrast the processes of asexual and sexual reproduction, both as seen in the Sea Monkey activity
	Probability Activity	Placeholder step – at this chronological point in the unit, students will do an in-class activity in which they flip a coin to determine the traits that two parents pass on to their offspring which is reproduced sexually; this will lead to an in-class discussion of diversity and variety
	Reflections on Probability Activity	Makes students' thinking visible by asking them to reflect on the amount of diversity created in the coin-flipping activity, the role that sexual reproduction plays in diversity, and the ways in which the activity would have gone differently if asexual reproduction were being examined, rather than sexual
	Notes to a Sixth Grader	Makes students' thinking visible by asking them to explain several concepts to a sixth grader

Table 3.3 cont'd

	Thinking About Our Mystery	Students make their thinking visible by reflecting on how the concepts in this Activity will help them solve the Fast Plant mystery
ACTIVITY 8 Solving Our Mystery	Have We Solved Our Mystery?	Introduces students to the final Activity of the unit
	The Fast Plant Mystery: Who's the Parent?	Asks students to determine which Fast Plant trait is dominant and which is recessive, and to determine the genotypes of both offspring generations of Fast Plants; finally, students are asked to determine both the phenotype and genotype of the missing parent plant
	Discussing the Fast Plant Mystery	Allows students to share their responses to the questions in the previous step with their classmates

Appendix B

Online Scaffolding Support Prompts in ‘From Genotype to Phenotype’ - Claim and Evidence

1. Introducing WISE . . .

   Practice notes

2. Will You Help Us Solve a Mystery?

   a. What do you think the color of the other parent (P2) in the Fast Plant family tree is?

      My claim is....

      Evidence to support my claim is...

3. Claims and Evidence

   a. Step 2: (thinking ahead)

      Living organisms have traits. These traits can be inherited or acquired. Do you know how different people inherit traits from their parents? Use the information you know to answer the following questions

      What are some traits that you have inherited from your parents?

      Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.

      Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

   b. Step 4:

      Do you think that Sawyer's claim answered the question of who the puppy's parent is? Please explain your answer. (Remember that a claim is an assertion or conclusion that answers the original question. Click Amanda the Panda for more hints)

      Do you think that Salena's claim answered the question of who the puppy's parent is? Please explain your answer

      What other information do you think that Sawyer and Salena need to answer the question? Please explain your answer

   c. Step 8:

Did Sawyer use the criteria to create a claim using evidence? (Please click on Amanda the Panda for hints) yes/no

Do you think Sawyer's claim is supported by enough evidence to answer the question of who the puppy's parent is? Is his evidence valid? Explain your answer

Did Salena use the criteria to create a claim using evidence?

Do you think Salena's claim is supported by enough evidence to answer the question of who the puppy's parent is? Is her evidence valid? Explain your answer.

d. Step 10:

Who do you think are the puppy's parents? Explain your answer. (Click on Amanda the Panda for more hints)

We think the puppy’s parents are… because…

e. Step 11 reviewing traits

   i. What are some traits that you have inherited from your parents?
   ii. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.
   iii. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

f. Step 12 Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree?

My claim is....

Evidence to support my claim is... (Please click on Amanda the Panda for hints)

4. <u>The Mechanism of Sexual Reproduction</u>

a. Step 4

How are an organism's genes and alleles related to its genotype and phenotype?

b. Step 7

How is a dominant trait different from a recessive trait?

c. Step 12

Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2; what new claim can you now make? What new evidence do you have to support your new claim? Click on Amanda the Panda for more hints)

My claim is….

Evidence to support my claim is… (Please click on Amanda the Panda for hints)

5. Looking More Closely at Sexual Reproduction
    a. Step 6

       What is the relationship between chromosomes, DNA and genes?

    b. Step 11

       How is the parent cell different from the daughter cells in meiosis?

    c. Step 15

       Let's say that in seals, the gene for the length of the whiskers has two alleles. The dominant allele (W) codes long whiskers & the recessive allele (w) codes for short whiskers. What percentage of offspring would be expected to have short whiskers from the cross of two long-whiskered seals, one that is homozygous dominant and one that is heterozygous?

    d. Step 17

       Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2; what new claim can you now make? What new evidence do you have to support your new claim? Click on Amanda the Panda for more hints)

       My claim is….

       Evidence to support my claim is… (Please click on Amanda the Panda for hints)

6. <u>Sexual and Asexual Reproduction</u>
    a. Step 2 (what I know)

       What do you already know about asexual reproduction? We know that…

       How is asexual reproduction different from sexual reproduction? The difference is…

       What are you looking forward to learning in this Activity? We want to learn…

    b. Step 4

       In what circumstances might sexual reproduction be better than asexual reproduction? Sexual reproduction is better when...

In what circumstances might asexual reproduction be better than sexual reproduction? Asexual reproduction is better when...

c. Step 6

Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction?

Heredity, meiosis, and reproduction are connected because...

Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better!

My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not?

d. Step 7

What do you know about asexual reproduction now that you've read about it?

What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages?

Was there any evidence in this activity that confused you? What was it?

What would you like to continue learning about reproduction?

7. <u>Plant and Animal Cells</u>

a. Step 4

Hi, it's Pat and I am in 6th grade. My teacher tried to teach us some new vocabulary the other day, and I got a little confused. How would you distinguish between an allele and a gene?

How would you tell the difference between a chromosome and a chromatid?

b. Step 9

What is the main difference between the processes of mitosis and meiosis?

c. Step 15

Hi, it's me, Pat, again. I was wondering: Why do different kinds of cells divide at different rates?

d. Step 16

Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2; what new claim can you now make? What new evidence do you have to support your new claim? Click on Amanda the Panda for more hints)

My claim is….

Evidence to support my claim is… (Please click on Amanda the Panda for hints)

8. <u>What Are the Traits of the Fast Plant Parent?</u>

   a. Step 2

      Record your Fast Plants results and share your observations with the rest of the class

      Number of Fast Plants with green stem were...

      Number of Fast Plants with purple stem were...

   b. Step 3

      What trait in your Fast Plants do you think is dominant? Which is recessive? Why do you think this?

      Think about the ratios that you've seen in your Punnett Squares. What do you think the genotypes of your F2 generation Fast Plants are? What about your F1 generation Fast Plants?

      What do you think the P2 plant must have looked like? What was its genotype?

   c. Step 4

      Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2; what new claim can you now make? What new evidence do you have to support your new claim? Click on Amanda the Panda for more hints)

      My claim is….

      Evidence to support my claim is… (Please click on Amanda the Panda for hints)

Appendix C

Online Scaffolding Support Prompts in 'From Genotype to Phenotype' (no claim & evidence version)

1. Introducing WISE . . .

   Practice notes

2. Will You Help Us Solve a Mystery?

   a. Step 3

      What do you think the color of the other parent (P2) in the Fast Plant family tree is?

      What do you think the color of the F2 generation will be?

3. Inherited and Acquired Traits

   a. Step 2 (what I know)

      What do you know about inherited and acquired traits? What would you say about inherited and acquired traits to someone who had never heard of traits?

      What are you looking forward to learning about inherited and acquired traits?

   b. Step 3

      Living organisms have traits. These traits can be inherited or acquired. Do you know how different people inherit traits from their parents? Use the information you know to answer the following questions

      What are some traits that you have inherited from your parents?

      Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.

      Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

   c. Step 6 (thinking about our mystery)

   d. Step 9 reviewing traits

      i. What are some traits that you have inherited from your parents?
      ii. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.
      iii. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

e. Step 10 (check point)

   What do you know about inherited and acquired traits now that you have read about them?

   Was there any evidence in this Activity that confused you? What was it?

   Is there anything about inherited and acquired traits that you would like to know more about?

4. The Mechanism of Sexual Reproduction

   a. Step 4 (checking my understanding)

      How are an organism's genes and alleles related to its genotype and phenotype?

   b. Step 7 (checking my understanding)

      How does a dominant trait different from a recessive trait?

   c. Step 12 (fast plants)

      Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2)

5. Looking More Closely at Sexual Reproduction

   a. Step 6 (checking my understanding

      What is the relationship between chromosomes DNA and genes?

   b. Step 11 (checking my understanding)

      How is the parent cell different from the daughter cells in meiosis?

   c. Step 15 (checking my understanding)

      Let's say that in seals, the gene for the length of the whiskers has two alleles. The dominant allele (W) codes long whiskers & the recessive allele (w) codes for short whiskers. What percentage of offspring would be expected to have short whiskers from the cross of two long-whiskered seals, one that is homozygous dominant and one that is heterozygous?

   d. Step 17 (fast plants)

      Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step

6. Sexual and Asexual Reproduction

    a. Step 2 (what I know)

       What do you already know about asexual reproduction? We know that…

       How is asexual reproduction different from sexual reproduction? The difference is…

       What are you looking forward to learning in this Activity? We want to learn…

    b. Step 4 (reflections)

       In what circumstances might sexual reproduction be better than asexual reproduction? Sexual reproduction is better when...

       In what circumstances might asexual reproduction be better than sexual reproduction? Asexual reproduction is better when...

    c. Step 6 (notes to 6th grader)

       Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction?

       Heredity, meiosis, and reproduction are connected because...

       Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better!

       My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not?

    d. Step 7 (checking understanding)

       What do you know about asexual reproduction now that you've read about it?

       What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages?

       Was there any evidence in this activity that confused you? What was it?

       What would you like to continue learning about reproduction?

7. Plant and Animal Cells

    a. Step 4 (notes to a 6th grader)

       Hi, it's Pat and I am in 6th grade. My teacher tried to teach us some new vocabulary the other day, and I got a little confused. How would you distinguish between an allele and a gene?

How would you tell the difference between a chromosome and a chromatid?

b. Step 9 (checking my understanding)

What is the main difference between the processes of mitosis and meiosis?

c. Step 14 (notes to 6th grader)

Hi, it's me, Pat, again. I was wondering: Why do different kinds of cells divide at different rates?

d. Step 15 (fast plants)

Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2)

8. <u>What Are the Traits of the Fast Plant Parent?</u>

   a. Step 2

   Record your Fast Plants results and share your observations with the rest of the class

   Number of Fast Plants with green stem were...

   Number of Fast Plants with purple stem were...

   b. Step 3

   What trait in your Fast Plants do you think is dominant? Which is recessive? Why do you think this?

   Think about the ratios that you've seen in your Punnett Squares. What do you think the genotypes of your F2 generation Fast Plants are? What about your F1 generation Fast Plants?

   What do you think the P2 plant must have looked like? What was its genotype?

   c. Step 4

   Based on information you learned from this activity, what do you think is the color of the other parent (P2) in the Fast Plant family tree? (Hint, you can revisit activity 2, step 2)

Appendix D

List of Scaffolding Prompts Scored

1. What are some traits that you have inherited from your parents? (pre)
2. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer. (pre)
3. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer. (pre)
4. What are some traits that you have inherited from you parent? (post)
5. Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer (post).
6. Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer (post).
7. How are an organism's genes and alleles related to its genotype and phenotype?
8. How is a dominant trait different from a recessive trait?
9. What is the relationship between chromosomes, DNA and genes?
10. How is the parent cell different from the daughter cells in meiosis?
11. Let's say that in seals, the gene for the length of the whiskers has two alleles. The dominant allele (W) codes long whiskers & the recessive allele (w) codes for short whiskers. What percentage of offspring would be expected to have short whiskers from the cross of two long-whiskered seals, one that is homozygous dominant and one that is heterozygous?
12. What do you already know about asexual reproduction? We know that…(pre)
13. How is asexual reproduction different from sexual reproduction? The difference is… (pre)
14. What are you looking forward to learning in this Activity?
15. In what circumstances might sexual reproduction be better than asexual reproduction? Sexual reproduction is better when...
16. In what circumstances might asexual reproduction be better than sexual reproduction? Asexual reproduction is better when...
17. Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Heredity, meiosis, and reproduction are connected because...
18. Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better!
19. My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not?
20. What do you know about asexual reproduction now that you've read about it?
21. What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages?
22. Was there any evidence in this activity that confused you? What was it?
23. What would you like to continue learning about reproduction?

24. Hi, it's Pat and I am in 6th grade. My teacher tried to teach us some new vocabulary the other day, and I got a little confused. How would you distinguish between an allele and a gene?
25. How would you tell the difference between a chromosome and a chromatid?
26. What is the main difference between the processes of mitosis and meiosis?
27. Hi, it's me, Pat, again. I was wondering: Why do different kinds of cells divide at different rates?

Appendix E

Scaffolding Prompts Rubrics

Table 5.20

Scaffolding Prompts Rubrics

<table>
<tr><td colspan="4">Rubric for Question 1 & 4: What are some traits that you have inherited from your parents?

Ideal response: eye color, skin color, natural hair color and texture, freckles, dimples, PTC (Phenylthiocarbamide) tasting</td></tr>
<tr><td>score</td><td>KI explanation</td><td>Description</td><td>Example of student work</td></tr>
<tr><td>0</td><td>No answer / Blank</td><td>Blank</td><td></td></tr>
<tr><td>1</td><td>Not correct/misconception</td><td>Students list acquired traits</td><td>Pierced ears</td></tr>
<tr><td>2</td><td>No KI
Students have isolated ideas. Ideas can also be a mixture normative and non-normative.</td><td>List both inherited and acquired traits</td><td>tattoo and eye color</td></tr>
<tr><td>3</td><td>Full KI
Makes scientifically valid claims</td><td>List at least two inherited traits</td><td>Eye color, hair color, skin color etc.</td></tr>
<tr><td colspan="4">Rubric for Question (2, 5): Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer.

Ideal response: False, offspring inherit from both parents. They get half from the mother and the other half from the father. Meiosis produces sex cells that have ½ chromosome number, when sex cells unit during reproduction the resulting offspring end up with a full set of chromosomes.</td></tr>
<tr><td>score</td><td>KI explanation</td><td>Description</td><td>Example of student work</td></tr>
<tr><td>0</td><td>No answer / off task</td><td>Blank</td><td></td></tr>
<tr><td>1</td><td>Not correct/misconception</td><td>Students show they have misconception</td><td>True, boys inherit more from their fathers than their mothers</td></tr>
<tr><td>2</td><td>No KI
Students have isolated ideas. Ideas can also be a mixture normative and non-normative.</td><td>Student have mixture of ideas</td><td>True, offspring inherit from both parents</td></tr>
<tr><td>3</td><td>Partial KI
Normative ideas without elaboration (meaning no explanations)</td><td>Give correct answer without elaboration</td><td>False, offspring inherit from both parents</td></tr>
</table>

Table 5.20 cont'd

<table>
<tr><td>4</td><td>Complex KI
(Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)</td><td>Give correct answer with elaboration</td><td>False, offspring inherit from both parents. They get half from the mother and the other half from the father.</td></tr>
<tr><td colspan="4">Rubric for Question 3 & 6: Is it true or false that girls inherit more traits from their mothers than from their fathers? Please explain your answer.

Ideal response: False, offspring inherit from both parents. They get half from the mother and the other half from the father. Meiosis produces sex cells that have ½ chromosome number, when sex cells unit during reproduction the resulting offspring end up with a full set of chromosomes</td></tr>
<tr><td>score</td><td>KI explanation</td><td>Description</td><td>Example of student work</td></tr>
<tr><td>0</td><td>No answer / off task</td><td>Blank</td><td></td></tr>
<tr><td>1</td><td>Not correct/ misconception</td><td>Students show they have misconception</td><td>True, girls inherit more from their mothers than their fathers</td></tr>
<tr><td>2</td><td>No KI
Students have isolated ideas. Ideas can also be a mixture normative and non-normative.</td><td>Student have mixture of ideas</td><td>True, offspring inherit from both parents</td></tr>
<tr><td>3</td><td>Partial KI
Normative ideas without elaboration (meaning no explanations)</td><td>Give correct answer without elaboration</td><td>False, offspring inherit from both parents</td></tr>
<tr><td>4</td><td>Complex KI
(Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)</td><td>Give correct answer with elaboration</td><td>False, offspring inherit from both parents. They get half from the mother and the other half from the father.</td></tr>
<tr><td colspan="4">Rubric for Question 7: How are an organism's genes and alleles related to its genotype and phenotype?

Ideal response: Alleles are different forms of genes. A gene is a functional unit of heredity. Genotype is the genetic make-up of an organism whereas phenotype is the physical appearance of an organism as determined by its genotype</td></tr>
<tr><td>score</td><td>KI explanation</td><td>Description</td><td>Example of student work</td></tr>
<tr><td>0</td><td>No answer / off task</td><td>Students do not attempt to answer the question</td><td>Blank/IDK</td></tr>
</table>

Table 5.20 cont'd

1	**Not correct**	Students give incorrect response	Genotype is the physical appearance of an organism
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students shows some isolated understanding on how these terms are related	Alleles are forms of genes that determine the genotype of an organism
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show understanding without elaboration	Alleles are different forms of genes. Genotype is the genetic make-up of an organism
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students show understanding with elaboration	Alleles are different forms of genes. Genotype is the genetic make-up of an organism whereas phenotype is the physical appearance of an organism as determined by its genotype

Rubric for Question 8: How is a dominant trait different from a recessive trait?

Ideal response: The traits due to dominant alleles are always observed, even when a recessive allele is present. Traits due to recessive alleles are only observed when two recessive alleles are present.

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Blank/IK	Blank/IDK
1	**Not correct**	Misconception	Only dominant traits get to be passed on
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Mixture of normative and non-normative ideas	Dominant and recessive traits are all passed on
3	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Complete response	The traits due to dominant alleles are always observed, even when a recessive allele is present. Traits due to recessive alleles are only observed when two recessive alleles are present.

Table 5.20 cont'd

Rubric for Question 9: What is the relationship between chromosomes, DNA and genes?

Ideal response: DNA are the molecules that make genes. Genes are the units of heredity. Genes make up the chromosomes. A chromosome is a thread that holds many genes

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Student does not attempt to answer the question	Blank/IDK
1	**Not correct/misconception**	Students give incorrect response	Chromosomes are found on the genes
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students show isolated ideas	DNA building block of chromosomes and genes
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show some understanding of the relationship without elaboration	DNA are the molecules that make genes.
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students show complete understanding of the relationship	DNA are the molecules that make genes. Genes make up the chromosomes. The chromosomes are the structures that house the genetic material

Rubric for Question 10: How is the parent cell different from the daughter cells in meiosis?

Ideal response: The daughter cell has half the amount of genetic material as the parent cell. The daughter cells has half the number of chromosomes as the parent cell

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Students do not attempts to answer the question	Blank/IDK
1	**Not correct/misconception**	Students show that they have misunderstanding of the differences	The daughter cell is the same as the parent cell
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students show some understanding without elaboration	Daughter cell has less genetic material than the parent cell

Table 5.20 cont'd

3	**Complete KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students show that they understand the main differences	The daughter cell has half the amount of genetic material as the parent cell. The daughter cells has half the number of chromosomes as the parent cell

Rubric for Question 11: Let's say that in seals, the gene for the length of the whiskers has two alleles. The dominant allele (W) codes long whiskers & the recessive allele (w) codes for short whiskers. What percentage of offspring would be expected to have short whiskers from the cross of two long-whiskered seals, one that is homozygous dominant and one that is heterozygous?

Ideal response: None (0%) of the offspring will have short whiskers

	W	W
w	Ww	Ww
w	Ww	Ww

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Students do not attempt to answer the question	Blank/IDK
1	**Not correct**	Students give incorrect responses	25% will have short whiskers
2	**Full KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)		none (0%) of the offspring will have short whiskers

Rubric for Question 12: What do you already know about asexual reproduction? We know that…(pre)
Ideal response: any correct response such as, it involves one parent, offspring gets it genetic material from one parent, etc

score	KI explanation	Description	Example of student work
0	**No answer**	Blank/Didn't make an attempt to answer the question	Blank

Table 5.20 cont’d

1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	Involves two parents
2	**Full KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students gives at least one correct characteristic typical of asexual reproduction	Offspring gets genetic material from one parent

Rubric for Question 13: How is asexual reproduction different from sexual reproduction? The difference is… (pre)

Ideal response: Asexual reproduction involves 1 parent unlike sexual that involves 2. Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents.

score	KI explanation	Description	Example of student work
0	**No answer**	Blank/Didn’t make an attempt to answer the question	
1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	Sexual reproduction produces stronger offspring
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students give a general/vague response. Give one difference and no mention of genetic material	Asexual reproduction involves 1 parent and sexual reproduction involves 2 parents
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show at least 2 differences	Offspring gets genetic material from 2 parents in sexual reproduction and from 1 parent in asexual reproduction
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students gives the ideal explanation	Asexual reproduction involves 1 parent unlike sexual that involves 2. Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents.

Table 5.20 cont'd

Rubric for Question 14: What are you looking forward to learning in this Activity?…(pre)

Ideal response: any response on what they ant to learn about reproduction

score	KI explanation	Description	Example of student work
0	**No answer**	Blank/Didn't make an attempt to answer the question	Blank/IDK
1	**Not correct/misconception**	If student says they are not willing to learn anything	We do not want to learn anything
2	**Full KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	If student identifies something on reproduction	We want to learn about the differences between sexual and asexual reproduction

Rubric for Question 15: In what circumstances might sexual reproduction be better than asexual reproduction? Sexual reproduction is better when...

Ideal response: mentions variation of offspring, getting genetic material from both parents can be advantageous if one parent has a genetic disease,

score	KI explanation	Description	Example of student work
0	**No answer /blank**	The student does not attempt to answer the question	Blank/IDK
1	**Not correct/misconception**	Students show that they believe sexual reproduction results in stronger offspring	Sexual reproduction produces much stronger offspring than asexual reproduction
2	**NO KI**	Mixture of ideas	
3	**Partial KI** Students have ideas on how sexual reproduction may be better than asexual reproduction	Identifies at least one advantage of sexual reproduction	mentions variation of offspring, getting genetic material from both parents can be advantageous if one parent has a genetic disease
4	**Full KI**	Identifies at least 2 advantages	mentions variation of offspring, getting genetic material from both parents can be advantageous if one parent has a genetic disease

Rubric for Question 16: In what circumstances might asexual reproduction be better than sexual reproduction? Asexual reproduction is better when...

Ideal response: fast production of offspring, no need to look for mate, fast production of food

Table 5.20 cont'd

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Blank – student does not attempt to answer the questions	blank
1	**Not correct/misconception**	Student mentions a misconception	Asexual reproduction is the only way plants can reproduce
2	**No KI**	Mixture of ideas	
3	**Partial KI** Students have ideas on how sexual reproduction may be better than asexual reproduction	Student identifies at least one advantage of asexual reproduction	fast production of offspring, no need to look for mate, fast production of food
4	**Full KI**	Identifies at least two advantages	fast production of offspring, no need to look for mate, fast production of food

Rubric for Question 17: Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Heredity, meiosis, and reproduction are connected because...

Ideal response: Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Students do not attempt to answer the question	Blank/IDK
1	**Not correct**	Students provide an incorrect response	There is no relationship between these processes
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students show isolated ideas about the concepts	Genetic material is passed through reproduction

Table 5.20 cont’d

3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students just provide definitions without elaboration	Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced).
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students provide definitions and elaborate indicating the relationship.	Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring

Rubric for Question 18: Also, I've been wondering: does sexual reproduction occur in plants? Please provide me with some evidence to back up your answer - that will help me to understand much better!

Ideal response: Sexual reproduction also occurs in some plants. For example, some plants have flowers with male and female parts. The transfer of pollen grains from anther to stigma is called pollination and leads to union of male and female cells.

score	**KI explanation**	**Description**	**Example of student work**
0	**No answer / off task**	Blank/students do not attempt to answer the question	
1	**Not correct/misconception**	Students show that they believe that plants do not reproduce sexually	Plants do not sexually reproduce

Table 5.20 cont’d

2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students shows some understanding that plants sexually reproduce	Yes, plants can sexually reproduce
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students shows some understanding that plants sexually reproduce but does not elaborate	Sexual reproduction occurs in plants, evidence is the presence of flower
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students shows some understanding that plants sexually reproduce and elaborate with examples	Sexual reproduction also occurs in plant. For example, some plants have flowers with male and female parts. The transfer of pollen grains from anther to stigma is called pollination and leads to union of male and female cells.

Rubric for Question 19: My last question is this: does meiosis happen in organisms that reproduce asexually? Why or why not?

Ideal response: meiosis does not occur in asexually reproducing organisms. Meiosis is a process of cell division that results in production of sex cells that have half the amount of genetic material. Asexually reproducing organisms do not produce sex cells so there is no meiosis in such organisms

score	**KI explanation**	**Description**	**Example of student work**
0	**No answer /blank**	Blank	
1	**Not correct/misconception**	Students link meiosis to sexual reproduction	Meiosis occurs in asexually reproducing organisms.
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students mention that meiosis does not occur in asexually reproducing organisms without elaboration or mix ideas	Meiosis does not occur in asexually reproducing organisms.
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show understanding that asexually reproducing organisms do not have meiosis but do not explain	Meiosis does not occur in asexually reproducing organisms. Meiosis is a process of cell division that results in production of sex cells

Table 5.20 cont'd

4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students give correctly mention that asexually reproducing organisms do not need meiotic division and fully explain why	Meiosis does not occur in asexually reproducing organisms. Meiosis is a process of cell division that results in production of sex cells that have half the amount of genetic material. Asexually reproducing organisms do not produce sex cells so there is no meiosis in such organisms

Rubric for Question 20: What do you know about asexual reproduction now that you've read about it? (post)

Ideal response: any correct response such as, it involves one parent, offspring gets it genetic material from one parent, etc

score	KI explanation	Description	Example of student work
0	**No answer**	Blank/Didn't make an attempt to answer the question	Blank
1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	Involves two parents
2	**Full KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students gives at least one correct characteristic typical of asexual reproduction	Offspring gets genetic material from one parent

Rubric for Question 21: What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages? (post)

Ideal response: Sexual reproduction involves two sex cells, male and female. (Students were given credit for mentioning that in asexual reproduction 1 parent is involved unlike sexual that involves 2). Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents. Sexual reproduction may result in variety of offspring unlike asexual where offspring is a replica of the parent. Asexual reproduction does not need a mate and usually faster than sexual reproduction

score	KI explanation	Description	Example of student work
0	**No answer /off task**	Blank/Didn't make an attempt to answer the question	

Table 5.20 cont’d

1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	Sexual reproduction produces stronger offspring
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students give a general/vague response. Give one difference and no mention of genetic material	Asexual reproduction involves 1 parent and sexual reproduction involves 2 parents
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show at least 2 differences	Offspring gets genetic material from 2 parents in sexual reproduction and from 1 parent in asexual reproduction
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students gives the ideal explanation	Asexual reproduction involves 1 parent unlike sexual that involves 2. Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents.

Rubric for Question 22: Was there any evidence in this activity that confused you? What was it? (post)

Ideal response: any response on what they want to learn about reproduction

score	KI explanation	Description	Example of student work
0	**No answer**	Blank/Didn’t make an attempt to answer the question	Blank/idk
1	**Mention a confusion**	If student says they are not willing to learn anything	We do not want to learn anything
2	**Full KI (explains the confusion)** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	If student identifies something on reproduction	We want to learn about the differences between sexual and asexual reproduction

Table 5.20 cont'd

3	**Says no confusion**	Coherently explains what they learned	Gives an example of what they learned – says not confused
Rubric for Question 23: What would you like to continue learning about reproduction? (post) **Ideal response:** any response on what they want to learn about reproduction			
score	**KI explanation**	**Description**	**Example of student work**
0	**No answer**	Blank/Didn't make an attempt to answer the question	Blank/idk
1	**Not correct/misconception**	If student says they are not willing to learn anything	We do not want to learn anything
2	**Full KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	If student identifies something on reproduction	We want to learn about the differences between sexual and asexual reproduction
Rubric for Question 24: How are an organism's genes and alleles related to its genotype and phenotype? Hi, it's Pat and I am in 6th grade. My teacher tried to teach us some new vocabulary the other day, and I got a little confused. How would you distinguish between an allele and a gene? **Ideal response:** Alleles are different forms of genes. A gene is a functional unit of heredity.			
score	**KI explanation**	**Description**	**Example of student work**
0	**No answer / off task**	Students do not attempt to answer the question	Blank/IDK
1	**Not correct**	Students give incorrect response	Genes and alleles are the same
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students shows some isolated understanding on how these terms are related	Alleles and genes have same function
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show understanding without elaboration	Alleles are different forms of genes.

Table 5.20 cont’d

4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students show understanding with elaboration	Alleles are different forms of genes. A gene is a functional unit of heredity.

Rubric for Question 25. How would you tell the differences between chromosomes and chromatid?

Ideal response: When a chromosome duplicates during cell division, the two strands are called sister chromatids. A chromatid is one of the two identical strands of DNA making up a chromosome.

score	**KI explanation**	**Description**	**Example of student work**
0	**No answer / off task**	Blank/Didn’t make an attempt to answer the question	Blank/IDK
1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	Chromosomes are chromatids
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students give a general/vague response	A chromatid is a duplicate of chromosome
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show knowledge that students different cells have different functions hence they divide at different rates	A chromatid is one of the two identical strands of DNA making up a chromosome.
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students demonstrate knowledge cell differentiation and elaborates giving examples	When a chromosome duplicates during cell division, the two strands are called sister chromatids. A chromatid is one of the two identical strands of DNA making up a chromosome.

Table 5.20 cont’d

Rubric for Question 26: What is the main difference between the processes of mitosis and meiosis?

Ideal response: mitosis is cell division that results in daughter cells that have the same amount of genetic material (chromosomes) as the parents. In mitosis cell divides into 2. In meiosis the parent cell divides into 4 cells that have half the amount of genetic material (1/2 number of chromosomes). Meiosis results in sex cells

score	KI explanation	Description	Example of student work
0	**No answer / off task**	Students do not attempt to answer the question	Blank / IDK
1	**Not correct**	Students give incorrect response	Mitosis is not different from meiosis
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students show isolated ideas	Mitosis result in 2 cells and meiosis result in 4 cells
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show understanding without elaboration	Mitosis is cell division that results in daughter cells that have the same amount of genetic material (chromosomes) as the parents. Meiosis the parent cell divides into 4 cells that have half the amount of genetic material (1/2 number of chromosomes).
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students show understanding with elaboration	Mitosis is cell division that results in daughter cells that have the same amount of genetic material (chromosomes) as the parents. In mitosis cell divides into 2. In Meiosis results in sex cells

Rubric for Question 27. Hi, it's me, Pat, again. I was wondering: Why do different kinds of cells divide at different rates?

Ideal response. Different kinds of cells divide at different rates because different cells have different functions. Cells that are responsible for growth and repair need to divide more frequently as compared to cells that are not for repair such as liver cells or nerve cells.

score	KI explanation	Description	Example of student work

Table 5.20 cont’d

0	**No answer / off task**	Blank/Didn’t make an attempt to answer the question	Blank
1	**Not correct/misconception**	Students writes incorrect response that shows some misconceptions	All cells divide at the same rate
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students give a general/vague response	Different cells divide differently because they are found in different parts
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show knowledge that students different cells have different functions hence they divide at different rates	Different kinds of cells divide at different rates because different cells have different functions.
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students demonstrate knowledge cell differentiation and elaborates giving examples	Different kinds of cells divide at different rates because different cells have different functions. Cells that are responsible for growth and repair need to divide more frequently as compared to cells that are not for repair such as liver cells or nerve cells.

Rubric for Question 21: What are some differences between asexual and sexual reproduction? How do these differences contribute to their disadvantages and advantages? (post)

Ideal response: Asexual reproduction involves 1 parent unlike sexual that involves 2. Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents. Sexual reproduction may result in variety of offspring unlike asexual where offspring is a replica of the parent. Asexual reproduction does not need a mate and usually faster than sexual reproduction

score	**KI explanation**	**Description**	**Example of student work**
0	**No answer**	Blank/Didn’t make an attempt to answer the question	
1	**Not correct (misconception)**	Students writes incorrect response that shows some misconceptions	Sexual reproduction produces stronger offspring

Table 5.20 cont'd

2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students give a general/vague response. Give one difference and no mention of genetic material	Asexual reproduction involves 1 parent and sexual reproduction involves 2 parents
3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students show at least 2 differences	Offspring gets genetic material from 2 parents in sexual reproduction and from 1 parent in asexual reproduction
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students gives the ideal explanation	Asexual reproduction involves 1 parent unlike sexual that involves 2. Asexual reproduction the offspring gets genetic material from one parent whereas in sexual the offspring gets from both parents.

Rubric for Question 17: Hi! I'm back again. I just have a few more questions for you. Can you help me understand the connection between heredity, meiosis, and reproduction? Heredity, meiosis, and reproduction are connected because...

Ideal response: Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring

score	**KI explanation**	**Description**	**Example of student work**
0	**No answer / off task**	Students do not attempt to answer the question	Blank/IDK
1	**Not correct**	Students provide an incorrect response	There is no relationship between these processes
2	**No KI** Students have isolated ideas. Ideas can also be a mixture normative and non-normative.	Students show isolated ideas about the concepts	Genetic material is passed through reproduction

Table 5.20 cont'd

3	**Partial KI** Normative ideas without elaboration (meaning no explanations)	Students just provide definitions without elaboration	Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced).
4	**Complex KI** (Scientifically complete and valid connections are made. Students provide an explanation(s) for their answer.)	Students provide definitions and elaborate indicating the relationship.	Heredity is a biological process where genetic material is transferred from parent to offspring. Meiosis if a type of cell division whose products are sex cells that have ½ the genetic material as compared to the parent cell. Reproduction is a process of generating offspring (biological process by which new organisms are produced). These processes are connected because meiosis produces sex cells that join during reproduction. These cells carry genetic material that is passed on to the offspring

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