THE ROLE OF PRIOR KNOWLEDGE, SITUATIONAL INTEREST, AND CASE STUDY PEDAGOGY IN THE UNDERGRADUATE BIOLOGY CLASSROOM.

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The Role of Prior Knowledge, Situational Interest, and Case Study Pedagogy in the Undergraduate Biology Classroom

A Dissertation Presented

by

ALLISON HUNTER

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of

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College of Education

Mathematics, Science, and Learning Technologies
The Role of Prior Knowledge, Situational Interest, and Case Study Pedagogy in the Undergraduate Biology Classroom

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ABSTRACT

THE ROLE OF PRIOR KNOWLEDGE, SITUATIONAL INTEREST, AND CASE STUDY PEDAGOGY IN THE UNDERGRADUATE BIOLOGY CLASSROOM

MAY 2018

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In the undergraduate science classroom, case study pedagogy is a method that uses stories with dilemmas and/or questions to convey scientific content. Case study pedagogy shows promise as an active learning pedagogy to meet the demands of 21st century biology education initiatives; however, there is a dearth of information on how students learn with case studies in the undergraduate biology classroom. The purpose of this study was to investigate variables that impact learning with case studies (prior content and contextual knowledge, situational interest, and pedagogical strategies) and the relationships between those variables to further understand how students learn with case studies in the undergraduate biology classroom. Results show that a particular pedagogical feature, small group work, moderates the relationship between prior content knowledge and situational interest. Along with increasing their knowledge of meiosis, students who had strong positive feelings that the narrative was connected to their learning (pedagogical strategies) had higher
achievement on a near transfer of knowledge item (learning) after the case study. These findings underscore the idea that case studies can be used in classrooms with stratified levels of prior content knowledge. These findings can facilitate the improvement of case study pedagogy with regard to the type and level of prior knowledge in the student population, the development of case study teaching materials, the training of faculty in case study pedagogy, and ultimately the widespread adoption of the practice.
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CHAPTER 1
INTRODUCTION

1.1 Overview

In their seminal work about why students leave their science, technology, engineering, and math (STEM) majors, Seymour & Hewitt (1997) reported on the impact that poor pedagogy had on student persistence in STEM disciplines. In their own voices, STEM undergraduate students who departed their STEM majors described the atmosphere of the “chilly” science classroom to be marked by poor teaching and a “weed-out” agenda. More specifically, women reported a gravitation toward the humanistic disciplines as a direct result of these deficits (Seymour & Hewitt, 2004). The field of biology education organized a formal response to these findings and formed a “call to action” to discuss and deploy a plan to improve undergraduate biology education for the 21st century (AAAS Vision and Change, 2011).

Vision and Change’s overarching statement was that undergraduate biology classrooms should employ methods of active learning. Active learning, a term often attributed to the undergraduate classroom, is used to described approaches to teaching that place the student at the center of the learning by using activities in which they participate in the learning process. Similar to student-centered learning in the K-12 classroom, active learning stresses engaging students actively with their learning processes. Problem solving and discussion based activities are examples of active learning techniques that shift
that focus to student participation rather than teacher-centered instruction.

Specific action items from the AAAS report include: “ensure that undergraduate biology courses are active, outcome-oriented, inquiry-driven and relevant; focus on conceptual understanding, not just on covering voluminous content; take biology out of the realm of the abstract and relate it to the real world” (AAAs Vision and Change, 2011 page 7). Case study pedagogy is a pedagogy that has been gaining interest in the undergraduate biology classroom and that aligns with these action items. The purpose of this study is to investigate the role of prior knowledge and situational interest during a case study on meiosis in the undergraduate biology classroom.

1.2 Case study pedagogy

In the undergraduate science classroom, case study pedagogy is method that uses stories with dilemmas and/or questions to convey scientific content. This pedagogy is novel to the science classroom and has been adapted from what is called case-based instruction in other fields such as law and business where it is the norm (Herreid, C. F., Schiller, N. A., Herreid, K. F., & Wright, C., 2011). The design and intent of case study pedagogy in the science classroom is to create learner-centered classrooms where the instructor role looks very different than in traditional lecture approaches. In case study pedagogy, the instructor facilitates learning through the use of discussion and storytelling. Case studies are designed not only to teach scientific concepts and content, but also to teach
process skills and critical thinking (Herried, 2007). Case study narratives can be all encompassing in order to contextualize scientific concepts, create emotional connections for students through characters and scenarios, and even demonstrate the nature of scientific problem solving which makes it a robust pedagogical approach rather than a teaching method.

Case study pedagogy in the undergraduate science classroom has garnered support not only via the faculty that utilize case studies, but also through National Science Foundation (NSF) funding. There is a National Center for Case Study Teaching (NCCSTS) that provides training for faculty on the pedagogy and also houses a repository of 572+ case studies in an array of life science disciplines. These case studies have been peer reviewed and include teaching notes for their deployment and adaption to particular classroom settings. However, there is little empirical evidence published on the process of learning with case study pedagogy in the undergraduate biology classroom. This is not lost on life science educators as a call for sound case study research has appeared in the literature that underscores a need for inquiry into the learning processes at work in case study pedagogy. The call also specified that mixed methodological approaches are needed to address research questions that would reveal the process of learning with case study pedagogy (Lundeberg & Yadav, 2006).

Empirical studies exploring the effects of case study teaching in the undergraduate biology classroom have begun to appear in the literature and
positive effects have been shown on student engagement (Smith et al., 2005) and achievement (Rabrcyck et al., 2006, Pai et al., 2010, Kang et al., 2011). Additionally, these studies have provided some description of the student populations that succeed with case study pedagogy such as biology majors and non-majors as well as documented gender differences (Kang et al., 2011, Lundeberg et al., 2011, Smith et al., 2005) and also demonstrated positive impacts for persons of color (Pai et al., 2010). Further, the role of the narrative has been examined to provide information on what types of stories make good case studies and may appeal to certain groups of students (for instance, male vs. female) (Lundeberg et al., 2011).

Although these findings make a compelling case for case studies in the undergraduate biology classroom, there is little research connecting a particular theoretical or conceptual framework of case pedagogy directly to a measurable outcome based in that theory. In order to advance the field of case study pedagogy in the science classroom, it is important to first examine the theory that case study pedagogy is based in, then align the empirical data that is available to provide a framework for further investigation. This process could help inform a conceptual framework specific to case study pedagogy in the undergraduate science classroom and help identify gaps in the knowledge about how students learn with case studies in this venue.
1.2.1 Theoretical underpinnings of case study pedagogy

Case study pedagogy in the science classroom does not have a singular theoretical approach. It was adapted from case-based instruction methods from business school and law school models, and is often cited alongside Problem Based Learning (PBL) that is widely used in health and engineering fields. By proxy, then, case study pedagogy in the science classroom has theoretical roots in cognitive psychology memory models such as Case Based Reasoning (CBR) and also Narrative Intelligence theory (Jonassen & Hernandez-Serrano, 2002). It has also been aligned with the tenants of social constructivism whereas case studies and PBL are widely used in constructivist learning environments (Jonassen, 1999).

CBR was first developed by Schank and Abelson (1975) from their work on how people, and machines, reason. CBR provides a memory model (Figure 1) for how information is stored and retrieved and then revised and re-used (Schank 1982, Kolodner, 1992). In the field of artificial intelligence, this model led to the development of case-based reasoning systems for storing and indexing cases or ‘stories’ to be applied to new situations. This model was also developed toward an application to learning by Kolodner (1992). “Learning by Design” is the direct outcome of the application of CBR in PBL classroom settings (Kolodner, 2003).
Turning to the ‘story’ portion of case studies, we can draw on Narrative Intelligence theory from cognitive psychology whereas the story itself has an impact on learning (Jonnasen, 1999). This aspect connects to work by Bruner (1990) who focused on the meaning making rather than the information processing aspect of cognitive function. Narrative Intelligence posits that stories provide a context in which we store information and then plays a role in how we retrieve information (Bruner, 1990). Information tethered to an emotional or memorable story is more readily encoded into long term memory and then more readily retrieved.
Finally, a third theoretical lineage for case study pedagogy comes from social constructivism. Vygotsky’s sociocultural theory of cognitive development (1978) describes learning as a social process where the learner brings own ideas, knowledge, and attitudes to the learning situation and connects new to old (Jonassen, 1999). Driver et al. (1994) further develops constructivist learning theory specific to the science classroom. Social constructivism in the science classroom presupposes that students possess some amount of scientific knowledge, whether it be “commonsense” or informal knowledge or prior experiences. Students do not learn science by abandoning this knowledge and simply acquiring new facts about phenomena. Instead, they enter into a new way of thinking about and providing explanations for the natural world. And, in order to do this they must engage in “discourse in the context of relevant tasks” (Driver et al., 1994, page 8). Case study pedagogy is delivered in alignment with this learning process as it is discussion based, draws on prior knowledge and beliefs, and seeks to help students connect what they know to new information through a narrative. The case study can provide discursive practice where students work through relevant problems and dilemmas using scientific knowledge. What’s more, the instructor, who is more knowledgeable, can structure the case study in such a way to enculturate students into the ideas and concepts of the biology community. It is with this constructivist perspective in mind, that the current research questions are framed.
1.2.2 Prior Knowledge in case study pedagogy

The concept of prior knowledge has been investigated in the PBL classroom to some extent but not in the case study classroom. In PBL, prior knowledge is often discussed as problem familiarity, which is defined broadly by PBL practitioners as the extent to which a problem matches a student’s content knowledge, contextual knowledge, and experiential knowledge (Sockalingham & Schmidt, 2013) and more narrowly by others as “the extent to which the student has had any previous experience with the events or phenomena described in the problem (Soppe et al., 2005).” Problem familiarity has been shown to have positive impacts on student learning and this has implications for the design of good problems (Sockalingham, 2010, Sockalingham & Schmidt, 2013, Soppe et al., 2005). In my unpublished work on case studies in the undergraduate biology classroom, a particular manifestation of prior knowledge, content knowledge, was investigated and found to be implicated in how students viewed learning with case studies. Students were asked to rate six different types of case studies in a non-major biology course according to how much biology they learned, how interested in learning biology they were during the case study, how much the case study helped them to connect the science to the real world, and how engaged they felt during the case study. Students with higher prior content knowledge rated a case study on meiosis significantly higher than students with lower prior knowledge. Conversely, students with lower prior knowledge rated a case study on evolution significantly higher than students with higher prior
knowledge (Hunter, A. unpublished data). These results suggest at the importance of prior knowledge for learning, though more research is necessary to determine sound relationships. A close look at all the case studies used in this study hint at other compensatory factors for prior knowledge such as more interest in a particular case study than at others. For example, one case study that was rated very high by students with low prior knowledge contained accessible contextual knowledge (the evolution of human kissing) and had very strong mechanisms for triggering the affective domain (i.e., situational interest) because it was about a lively, relevant topic (again, human kissing).

1.3 Situational interest in the undergraduate biology classroom

Hidi and Renninger define interest as a motivational variable that refers to one’s likelihood to engage with particular content. Interest has both affective and cognitive components that are separate but that interact and the role of the affective and cognitive components vary throughout interest development (2006). The development of interest flows from two phases of situational interest (triggered then maintained) to two phases of Individual interest (emerging then well-developed). Individual interest is described as a predisposition to react to a particular stimulus or content. Situational interest can be triggered by context-specific events and can be temporary. For example, a student may possess individual interest in biology and enter a biology course with a high level of interest in engaging with and learning biological concepts.
On the other hand, any student with or without strong individual interest for biology, may encounter a laboratory experiment in a biology course that has to do with how mice learn in amaze and their situational interest is by the object (mouse) perhaps due to the novelty of handling the mouse. For example, in a study that took place in an undergraduate zoology laboratory course, sources for the triggers of situational interest were investigated. Live animals, an “ah-a” moment of discovery, a meaningfulness (relatable, i.e. about the human body), social involvement (lab group work), and humor were found to be triggers of interest (Dohn, Madsen, & Malte, 2009). Although this study did not connect these triggers of interest to learning outcomes, situational interest has been shown to influence paying attention, goals, and levels of learning repeatedly in the literature (Hidi & Renninger, 2006). Because case study pedagogy relies on using rich narratives that contain a novelty of characters and situations, hands-on working with real data, and the stimulation of emotions to draw students in to the learning process, situational interest should be investigated in relation to learning outcomes in the case study classroom.

1.4 Difficulties Learning Meiosis

Meiosis, the type of cell division that leads to the production of gametes (egg and sperm), is a fundamental biology concept that is taught in both non-major and major undergraduate biology courses typically in conjunction with mitosis, the cell division mechanism of somatic (body) cells. Meiotic concepts
are difficult to learn and many students possess misconceptions and alternative conceptions at the freshman level that persist throughout their upper level courses (Lewis 2000; Ozcan, Yildirim, & Ozgur, 2012; Kalas et al., 2013). For example, students have difficulty with the hierarchy of structure for DNA, genes, and chromosomes (common misconception: DNA is composed of chromosomes) (Yildirim, & Ozgur, 2012) and also with the differences between mitosis and meiosis surrounding chromosome number (Lewis, 2000).

In my recent unpublished work about case studies, a case study about mules and meiosis was used in an undergraduate, non-majors course and was rated more favorably by students who possessed higher levels of biology content knowledge (Hunter, A, data not published). The interpretation of this prior content knowledge finding is limited by the fact that it was measured using a concept inventory that included many biological concepts, not just meiotic concepts. A role for prior content knowledge in the case study classroom could be furthered by using a more reliable measure for prior content knowledge with a case study about a mule and meiosis.

1.5 Conceptual framework

The empirical evidence thus far has provided some insight as to the types of student variables (gender, ethnicity) and the types of outcome variables (achievement, attitudes) that are part of the framework for being successful with case studies and these will be reviewed in the next chapter. The theoretical
framework on which case study pedagogy builds upon (constructivism) suggests that building on prior knowledge is also a key factor in case study learning. In my previous work I found students’ perceptions of the case studies to be associated to their level of prior knowledge; particularly, a case study about meiosis was rated disparately by students with varying levels of prior biology content knowledge (Hunter, A. data not published). From the literature, we know that situational interest plays a key role in whether or not students engage in the cognitive processes and behaviors that lead to learning and so should be considered in the framework for learning with case study pedagogy.

Figure 1.2 shows the conceptual framework that guides this study. Students come into the learning situation with an entire set of prior knowledge that can include both content and contextual knowledge. At the beginning of the case study, students encounter a story or problem that serves as a trigger of situational interest (i.e. the story of a mule miraculously giving birth). As the case study proceeds, difficult biological concepts (cell division, homology, chromosome structure) are called into play in order to work with the case study. Some students may have prior knowledge of these concepts which plays a role in maintaining situational interest and therefore staying engaged with learning with the case study. Others may not, yet there could be other factors that enable them to stay interested in the case study. One factor could be that they possess contextual knowledge as related to the case study narrative (i.e. mules, animals, veterinarians, farms). Another factor could be that the pedagogical moves built
into case studies (i.e. group work, discussions, learner-centered approaches) enable them to maintain interest in the case study work. In addition, all of these factors (prior content knowledge, prior contextual knowledge, and pedagogical features) may play a role in concert for maintaining situational interest and allow for learning of the concept.

Figure 1.2: A conceptual framework for the role of prior content knowledge and situational interest in the case study classroom that informs this study.

1.6 Problem Statement

Case study pedagogy shows a lot of promise as an active learning pedagogy to meet the demands of 21st century biology education initiatives; however, there is a dearth of information on how students learn with case studies in the undergraduate biology classroom. Understanding the variables that impact learning with case studies (e.g., prior content knowledge, interest in
biology, pedagogical strategies) and any relationships between those variables is necessary to understand how students learn with case studies in the undergraduate biology classroom. Such findings could inform the improvement of case study pedagogy with regard to appropriate student populations, the development of case study teaching materials, the training of faculty in case study pedagogy, and ultimately the widespread adoption of the practice.

1.7 Research Questions and Study Purpose

The purpose of this study is to investigate the role of prior knowledge and situational interest in the case study classroom. Specifically, the following research questions will guide this study:

1) How does prior content knowledge impact student learning with case studies?
2) How does prior contextual knowledge impact student learning with case studies?
3) What kind(s) of prior knowledge helps students maintain interest in the case study classroom?
4) How do case studies (pedagogical moves) help students maintain interest in the absence of prior content knowledge?
5) On a conceptual level, to what extent do all three of these variables (contextual PK, content PK, and pedagogical moves) impact learning with case studies? (note: not on a multivariable statistical level)
2.1 Case study pedagogy in the undergraduate biology classroom

One of the first empirical studies to appear in the literature regarding the use of case studies in the undergraduate biology classroom was a study that sought to completely re-design a traditional microbiology lecture into an active learning environment (Smith et. al., 2005). The entire course was changed to include a large online resource component and to devote a majority of class time to active learning rather than lecture. One of the active learning pedagogies chosen was case studies. Three case studies were introduced into the course from the NCCSTS repository and class time was devoted to discussions and problem-solving group work related to the case studies. Although many broad changes to the course were deployed and assessed, there were a few findings specific to the case study portion of the course.

Among other questions on a survey about the different course components, students were asked to rate “How useful did you find case studies in helping you see the relevance of course material?” Of the 340 students that answered 17% chose “One of the most useful parts of the course,” and 52% students chose the next level of “Very helpful”. In the same survey, students were asked an open-ended question about what they liked about the use of case studies in the course. Of the 339 students responding, 123 students indicated that they liked
how cases helped them to learn/think about/apply course concepts, 128 students described how cases allowed them to see the real-world relevance of course concepts, and 79 students reported that the case studies made the course concepts more interesting or more engaging. Nine students indicated that the case studies had no value and that the case-study work was either busywork or too much work in general (Smith et. al., 2005). While this study has limitations in that it was looking at multiple course changes and innovations at once and only two survey items were devoted to case study assessment, it did set the stage for investigating case studies in large biology classrooms since students reported favorably on their use in the context of many active learning techniques being deployed at once.

In 2006, Rybarcyk and colleagues demonstrated an increase in learning gains for students who learned about cellular respiration in a case-based approach in comparison to those who learned the same concepts in standard lecture. (Here it is important to understand that what the authors chose to call case-based approach is what is being discussed as case study pedagogy in this paper. The investigators used published case studies from the NCCSTS repository.) The study took place in an undergraduate biology lecture courses where the case-based approach or the standard lecture approach were assigned to each course. The analysis was based on a sample size of 75 students for the case-based approach and 45 students for the standard lecture approach. A statistical difference was found between the learning gains of the case-based approach
group. The authors conclude that based on their findings, the use of case teaching in science is an effective approach for students to learn biological processes in relevant, real-world contexts that results in significant learning outcomes. They suggest further research on whether case-based leads to long-term content retention (Rybarcyk et al., 2006).

In a study by Knight et al. (2008) four cases were integrated into the curriculum of an upper level molecular biology laboratory course at a minority-serving university. Prior to the intervention, laboratories were taught with standard “cook book” protocols. Four cases were developed that contained roles portrayed by individuals that reflected the student population. For example, the medical investigators in one case are Hispanic, and in another case a young Chinese man is seeking DNA evidence of his ancestry. Interview data was collected and analyzed for eight students in the course and students reported positively that the case studies helped them make a connection to the science. Survey data (n=18) demonstrated that students maintained their positive attitudes toward a career in biology; an effect not seen in prior use of ‘cook book’ laboratories.

All of the above described studies looked at the student aspect of case study pedagogy. There is very little information focusing on the instructor aspect of case study pedagogy. To date, there has been one study to capture faculty’s experiences with case study pedagogy in the science classroom (Yadav et al., 2007). One hundred and thirty nine faculty were identified via a roster from the
NCCSTS conference and invited to participate in the survey by email. A response rate of 73% was obtained and the responders were mostly teaching at the university level with 4% of respondents teaching at the high school level. Twenty-three states were represented in the responses and 62% of respondents were women (Yadav et al., 2007). The results of the survey showed that faculty perceived case study pedagogy as a pedagogy that can address some of the common problems associated with teaching science such as engagement with and retention of content. A majority of faculty (93.8%) agreed that students were more engaged in class when using cases and that students were better able to apply course content to practical applications (91.3%). Faculty also mostly disagreed (87.5%) with the notion that students retained less course content where cases were used (Yadav et al., 1997). This study provides an instructor perspective about their students that aligns with what has been discussed in the literature with regard to student engagement and learning. However, it does not provide any instructor information in the form of reflection on their case study pedagogy, nor any potential instructor variables that may interact with the case study environment. One notable item is that of the faculty that responded, 62% were women. It would be important to know if this reflects the gender population of instructors attending the training, and if so, gender may be a variable at the instructor level in similar ways that it is at the student level.

Finally, there is the aspect of the case study itself and the variables that it may bring to the broader picture of learning with case studies. There was some
evidence presented in the above studies that indicate that the type of story or narrative has an impact on student’s experiences with case study pedagogy (Kang et al., 2011, Knight et al., 2010). Further, a comprehensive analysis of case study development papers yielded a conceptual framework for developing case studies. Kim et al. (2006) looked at 100 studies that dealt solely with the development aspect of case studies across multiple disciplines. The majority of papers came from the medical (40%), education (28%) and business (13%) fields and not specifically the sciences; however the key concepts they synthesized by reviewing the structure and development of case studies are applicable and relevant to case study pedagogy in any discipline. Figure 2 shows the conceptual framework put forward by Kim and colleagues (2006). They used the categories of content, structure, attribute, and process to organize the themes they synthesized from the strategies of case study development as reported in the 100 studies/papers (Figure 2.1). They also summarized and mapped the 17 strategies they found to five core attributes of case studies: relevant, realistic, engaging, challenging, and instructional (Kim et al., 2006). It is notable that so many of the content strategies (first row in Figure 2.1) map directly to the development of the narrative or story. Additionally, a key developmental feature of process (last row in Figure 2.1) is the concept of building on prior knowledge. The importance of the narrative and the incorporation of prior knowledge both map directly back to the theoretical underpinnings of case study pedagogy.
2.2 Prior Knowledge

In their review of the prior knowledge literature, Dochy, Segers, & Buehl concluded that theorists held both very vague and broad definitions of prior knowledge and that prior knowledge was often an umbrella term under which many more precise terms for prior knowledge were specified (1999). For example, in the literature appears terminology such as experiential knowledge, background knowledge, and personal knowledge which are used to refer to portions of one’s prior knowledge. Prior knowledge itself has alternative monikers in the literature such as pre-knowledge, current knowledge, and expert knowledge which makes this a difficult concept to both research and communicate about (Dochy, Segers, & Buehl, 1999). As stated earlier, case study pedagogy draws on constructivist principles in that it inherently activates and
utilizes prior knowledge. From a constructivist viewpoint, prior knowledge is broadly defined as “the knowledge, skills, or ability that students bring to the learning process” (Jonnasen & Grabowski, 2012, page 417). In addition, one cannot overlook that prior knowledge does not necessarily mean accurate knowledge. Misconceptions, alternative conceptions, and naïve knowledge are also a part of the prior knowledge domain (Dochy, Segers, & Buehl, 1999). Students with common scientific misconceptions have been well documented in many fields including physics, chemistry, and biology education (Clement, 1982, Nekhlah, 1992, Chi, 2005, Ozcan, Yildirim, & Ozcur, 2012) and the relationship between prior knowledge (misconceptions) and conceptual change has been at the center of prior knowledge research for decades (Gilbert & Watts, 1983).

In the case study environment, we can begin to imagine that multiple, specific types of prior knowledge (knowledge about the content, knowledge about the storyline) could be activated. Although not investigated in the case study classroom, the concept of prior knowledge has been investigated in the PBL classroom. PBL researchers have delineated which sort of prior knowledge they are measuring and also coined a new term for discourse in PBL research called “problem familiarity”. In PBL, problem familiarity is defined as the extent to which a problem matches a student’s content knowledge, contextual knowledge, and experiential knowledge (Sockalingham & Schmidt, 2013) and more narrowly by others as “the extent to which the student has had any previous experience with the events or phenomena described in the problem.
Problem familiarity has been shown to have positive impacts on student learning and this has implications for the design of good problems (Sockalingham, 2010, Sockalingham & Schmidt, 2013, Soppe et. al., 2005).

2.2.1 The role of prior knowledge in learning

In the PBL classroom, a positive relationship between problem familiarity and student learning was found. In a recent study, problem familiarity was defined as the extent to which a problem matches a student’s content knowledge, contextual knowledge, and experiential knowledge (Sockalingham & Schmidt, 2013). The researcher’s hypothesized that the level of problem familiarity has an impact on student learning. Specifically, they asked whether or not students differentiate between familiar and unfamiliar problems and if a familiar problem leads to different learning outcomes than an unfamiliar problem. For learning outcomes they looked at student interest in the problem, learning issues, critical reasoning, and collaborative learning. The research took place at a polytechnic university that had adopted PBL as its approach to enriching the first year student experience. Students in the study were enrolled in a problem solving course titled “Cognitive Processes and Problem Solving” and this was their second semester of being immersed in PBL. A total of 172 students were enrolled in the course and, therefore, the study. Two problems were chosen by the researcher who is also the module coordinator for the PBL course. (In the PBL model there are typically course coordinators and then a cadre of tutors
(facilitators) who work with the students in the PBL classroom setting). Based on prior experience with the course module, the researcher chose the familiar problem to be on “knowledge and morality” and the unfamiliar problem to be “realism and anti-realism”. Data were collected from two sources: the students in the course and the tutors in the course. It was not clearly stated how many tutors participated nor was it clearly stated if they were completing a measure for each student. However, embedded within the analysis, we see that the DF used for the tutor analyses is 171, so we can assume that a measure was done for each student (N=172). Validated instruments to measure insert specific constructs and were filled out by students themselves and also by the tutors to capture their perceptions of each student’s learning. However, the emphasis of the findings were on the students self-reporting on their learning. Insert type of learning they called it learning was higher for the familiar problem when compared to the unfamiliar problem. However, contrary to what was predicted, there was no significant difference in promotion of collaborative learning nor stimulation of critical reasoning between the two problems. A critique of this paper is that it is monomethod and some explanatory qualitative data about student learning experiences with each problem would have helped situate this unexpected finding.
2.3 Interest

Broadly, interest is a motivational construct that functions in both the cognitive and affective domain (Hidi, Renninger, & Krapp, 2004). Beyond a general sense of “liking”, interest also includes a person’s willingness to take action beyond what they normally would, had their interest not been triggered. The more interested in a particular content a student is the more willing they will be to engage in behaviors, such as information seeking, in order to learn (Renninger, 2000). Like prior knowledge, interest, is a construct in the literature that has been differentially defined by theorists and has some disparity in the terminology that is used in the discourse surrounding interest.

The definition of interest used in this study based on the work of Hidi and Renninger who define interest as “the psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time” (2006). In this study, we will consider the classes of objects, events, or ideas to be the case study and the content which it conveys. Further, this study draws on the four-phase model of interest development by Hidi and Renninger (2006) that distinguishes between two types of interest, situational and individual, over four phases (see Figure 2.2). Situational interest can be triggered by context-specific events and can be temporary while Individual interest is described as a more persistent state that can develop over time. Situational Interest refers to an early stage of interest development and can be elicited by a
particular situation which would contain some novelty, a level of intensity, or an attractiveness of content. Individual interest can develop in part from the situational experiences but can also exist due to external sources. For example, students may enter a situation with well-developed biology interest due to their environment (parental influence) and the academic goals they have defined for themselves (biology major). Individual interest can predispose a student to a triggering event because of new content or a new challenge that is presented (Hidi & Renninger, 2006).

![Four-phase model of interest development]

**Figure 2.2:** The four-phase model of interest development. (Adapted from Hidi, S., and Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*. 41(2): 111-127.)

This study focuses on situational interest and situational interest has two phases: triggered and maintained. Triggering situational interest refers to a short-term change in cognitive and affective processes, for example perking up or looking up due to an environmental cue. Maintained situational interest
refers to a state that follows the triggering event but yields focused attention or persistence over a period of time (Hidi & Renninger, 2006).

In a recent study of middle school aged students participating in a summer residential program for talented students by Linnenbrink-Garcia, Patall, & Messersmith, situational interest was positively associated with two learning outcomes: student’s perceived competence in science and also to instructor-rated engagement which amounted to the rating of behaviors related to participation in activities and discussions as well as the depth of those interactions (2013). This study also aimed to tease out specific pedagogical practices that were associated to situational interest. They found positive associations between three pedagogical approach variables and situational interest: connections to real life which included use of stories that related the course material to real life; instructor approachability whereas the instructor was rated on four items as humorous, friendly, approachable, and enthusiastic; and perceived choice in the classroom which rated how autonomous students felt over their learning activities in the classroom. All three of these variables were predictors of situational interest. In addition, maintained situational interest was found to be a mediator of a positive relationship between how students perceived their provision of choice in the classroom and their instructor-rated engagement. These findings are strengthened by the fact that there was a large sample size (N=126) and the researchers were able to control for individual interest that was measured as students entered the program. The
researchers interpreted these findings to mean that classroom practices can have an effect on situational interest. They specifically posit that autonomy over one’s learning has a strong positive impact on both triggering and maintaining situational interest, that the instructor’s approachability can act as a trigger for situational interest and hook students into the learning context or situation, and that connecting the course content to real life has an impact on maintaining situational interest. And, within this same study context, levels of situational interest were associated with the learning outcomes of perceived competence in science and instructor-rated engagement, making a strong case for the role of specific classroom practices on the different phases of triggering situational interest and maintaining situational interest (Linnenbrink-Garcia, L., Patall, E.A., & Messersmith, E.E., 2013).

Closer to the case study classroom and the present study’s research context, situational interest has been shown to have an influence on academic achievement in the PBL context. In a study by Rotgans and Schmidt, situational interest was found to have an impact on achievement over the course of a single PBL unit (2009). In a second-year course in economics taught solely by PBL, 69 students split among four course sections, took part in the study and the learning outcomes measured were direct, daily measures of student’s conceptual mapping of the day’s content using the Concept Recognition test. The test was administered pre and post to the PBL activities each day. In addition, achievement-related classroom behaviors were measured using a scale
administered to the tutors who were facilitating the students in the PBL group settings. Tutors rated the students on their participation, teamwork, presentation skills, and self-directed learning. While no significant relationship was found between situational interest and the student’s abilities on the Concept Recognition scores, there was a significant positive relationship between situational interest and the tutor observed achievement behaviors, and this was later shown to be moderately (.47) correlated to a final written test of the material covered by the problem used during the study. The stated implication for these findings were that achievement based behaviors could serve as a mediator between situational interest and achievement, but that without engagement and resulting behaviors on part of the student, situational interest alone cannot predict subsequent achievement. There must be opportunities in place in the learning context for students to enact these behaviors so that learning may occur (Rotgans, J.I, & Schmidt, H.G., 2011).

2.4 Learning Meiosis

Science is difficult to learn and one reason for this is that many of the ideas underlying scientific concepts are beyond our senses and exist at a micro or intangible level (Johnstone, A. H., 1991). This has been demonstrated particularly in chemistry education where difficulty learning chemistry concepts on students have difficulty making connections between the content and concepts at the symbolic (ex: chemical equation), the macro (ex: salt dissolves in
water), and the sub-micro (ex: molecular structure of salt) scale. Teachers, with their more expert level of conceptual knowledge, may switch between these levels of during teaching without making the connections between the levels explicit to students. In fact, a lot of teaching tends to occur using a combination of all three levels but students may be stuck at one level or only possess one level of conceptual understanding (Johnstone, A. H., 1991, Gable, D., 1999). The field of biology also possess three levels of content and concepts: the macro (ex: plants and animals), the micro (ex: cells and organelles), and the symbolic (ex: DNA, ATP). It has been demonstrated that biological concepts that students struggle with are those that rely on a symbolic schematic to represent a complex molecular set of processes, such as molecular processes of transcription and translation, and that students have a persistent misinterpretation of certain parts of the symbolic language actually represent (Wright, L. K., Fisk, N., & Newman, D.L., 2014). Similarly, with cell division concepts, where chromosome cartoons are meant to represent complex molecular structures, students often fail to understand the underlying molecular structure and how these are conceptually connected to other concepts like genes and heredity (Lewis, J., 2000).

Kozma defined a spectrum for scientific knowledge in which you have the experts, or holders of scientific knowledge, and novices who have less experience, literacy, and conceptual understanding of scientific content. What’s more, those with expert prior knowledge have an entirely different set of
knowledge available to them when they encounter a new problem or context (2003). In the context of learning from problem solving and borrowing from the expertise literature, a framework for robust knowledge utilizes the scale of expert to novice to describe what having robust knowledge means. For example, an expert with robust knowledge would have deep, connected, and coherent knowledge while a novice would demonstrate surface, fragmented, or inconsistent knowledge. A key feature of the expert level connected knowledge, is demonstrated ability to transfer knowledge across contexts and domains and transfer assessments can aid in distinguishing between robust knowledge and shallower, novice knowledge (Richey, J. E., & Nokes-Malach, T. J., 2014).

Classrooms that use problem-solving instruction, has been shown to aid in the development of robust knowledge (Richey, J. E., & Nokes-Malach, T. J., 2014) and specifically in PBL, students demonstrate more elaborated knowledge and transfer of knowledge rather than short-term content recall (Dochy, F., Seagers, M., Van den Bossche, P., & Gijbels, D., 2003). In this study, the framework of robust knowledge will be used to define learning in the case study pedagogy context by assessing expert-level knowledge through a meiosis concept inventory which was validated using expert and novice explanations of meiotic concepts (Kalas, K., 2013) and to assess the connected knowledge experts possess by using a near transfer question to measure student’s ability to transfer knowledge from the case study context to a new novel context (Richey, J. E., & Nokes-Malach, T. J., 2014).
2.5 Conclusion

There is reasonable empirical evidence to suggest case study pedagogy has merits related to positive learning outcomes for students in undergraduate science classrooms. We know from the research on prior knowledge and interest that activities that activate prior knowledge, trigger situational interest, and activities that foster the maintenance of situational interest are key to student learning. PBL is one such pedagogy that has been explored with regard to these variables, and learning outcomes that result from PBL settings are specifically long-term retention and transfer of knowledge or skills to a new context. Specific to the undergraduate science classroom, we see that many scientific concepts are very difficult for students to learn. It is plausible that maintaining interest to go do that difficult learning is a key step for students working with difficult scientific concepts. Additionally, prior knowledge (in its many forms) has a role in moderating situational interest which leads to learning. By design, case study pedagogy has all of the elements for drawing on multiple forms of prior knowledge and also multiple avenues for triggering and maintaining situational interest. Next steps to detail the role(s) of prior knowledge and situational interest in the case study classroom are crucial for fully understanding and harnessing the power of the pedagogy so that it can lead to student learning.
3.1 Methods Overview

In order to answer these research questions, a mixed-method approach was utilized; a sequential explanatory approach (QUAN→qual) with a larger quantitative wave (N=25) and a subsequent smaller qualitative wave (N=9). Sequential explanatory was chosen so that the quantitative relationships could be further explained using qualitative findings (Creswell & Plano Clark, 2011). In this study context, although quantitative data would provide an overall picture of the relationships between variables, the qualitative data could help refine the understanding of these relationships and help with understanding how the variables were associated.

Students in an undergraduate biology course were exposed to a case study on meiosis (cell division) that employed a narrative about a mule giving birth and the farmer trying to solve the mystery of the offspring’s paternity (See Appendix A). Both quantitative and qualitative data were collected to measure student's prior meiosis knowledge; contextual knowledge (knowledge they held about elements of the story such as horses and mules); their situational interest; their beliefs about and feelings toward the pedagogical features and the role of the narrative on their learning. Learning outcomes for meiosis were assessed post case study using a meiosis concept inventory, a near transfer question, and
items to measure student perception of their learning during the case study.

Think-a-loud interviews (described below) were conducted to collect the qualitative data that was used to explain the quantitative findings. Finally, demographic variables such as gender, major, and ethnicity were collected to help describe the sample population and define the limitations of the study.

Figure 3.1 shows the concepts and manifestations for this study.

**Figure 3.1**: Concepts and manifestations for the study. The concepts under investigation in this study are shown in purple ovals, sources of quantitative data are shown in blue boxes, and sources of qualitative data are shown in green boxes.

3.2 Research Context

The research site is a comprehensive medium sized, primarily undergraduate, public university within the state system of a Mid-Atlantic state.
The student body is 61% female with 27% minority students. The university offers undergraduate degrees in over 40 programs, plus 15 graduate programs and various certificate and preparation programs and in 2015, 2,185 degrees were awarded. Approximately 85% of the student population receives financial aid.

The study took place in a general introductory biology course for non-majors called: Science for Citizen Leaders. Twenty-nine students enrolled in the course and all students consented to participate in the study. However, between 4 and 6 students failed to complete each measure in this study so sample size varied for individual instruments. Demographic data were collected on 25 students. The gender identity composition was 24% female. The race of the population consisted of 8% Asian/Pacific Islander, 16% Hispanic/Latinx, 24% African/African American/Caribbean and the ethnicity of the population was 28% Hispanic or Latinx. The average age for the population was 23.8 years old and there were 32% first years, 12% second years, 36% third years, and 20% fourth year students in the course. Nineteen of the 25 students reported their overall GPA and the average was 3.31 out of 4 points.

In this course, class periods occurred twice per week on a Tuesday/Thursday schedule for 110 minutes per meeting. One Thursday class period was devoted to deploying the case study from start to finish. It was used in the course directly after the Tuesday class period where DNA, genes, and cell
division topics were covered through a lecture format and students had a textbook reading assigned for this unit.

The researcher for this study does not reside with the intervention site for this study context. Therefore, IRB approval was first sought through the intervention site’s IRB that included a full review. Then, IRB determination was attained through the researcher’s IRB and the study proceeded under the intervention site’s approved protocol. Informed consent to participate in the study was obtained by signed consent form by the instructor prior to the start of the research activities and then verbal consent was confirmed by the researcher prior to beginning the think-a-loud interviews.

3.3 Quantitative Data Collection

Appendix B contains the instruments that were used in this study. The following provides a description of each instrument and the variables that were created for the study using the resulting measures.

3.3.1 Meiosis Concept Inventory

The meiosis concept inventory was developed to assist instructors in detecting misconceptions associated with understanding how chromosomes separate during the process of meiosis. In addition, it can be used as a tool to measure the effects of specific learning activities. The instrument is validated and consists of 17 questions, testing five independent concepts within meiosis (Kalas et al. 2013). For this study, items 1-8, 14, and 15 of the Meiosis Concept
Inventory were administered prior to the case study and used to measure prior content knowledge. Items 1-5 & 14-17 of the Meiosis Concept Inventory were used after the case study and used to measure meiosis learning.

3.3.2 The Beliefs About Case Studies (BACS) Scale

The Beliefs About Case Studies (BACS) Scale was developed by the researcher to measure the ways in which students experience learning with case studies. This is not a validated instrument, however construct validation had been established prior to this study and reliability was established using the data collected in the present study (below). Items on the scale draw on four categories: Role of the Narrative, Pedagogical Features, Prior Knowledge, and Perceptions of Learning.

Prior to data analysis, the validity and reliability of the Beliefs About Case Study (BACS) Scale were examined. During the development of the instrument and the item design, construct validity was established (see Construct Map Appendix C) using the literature and pedagogical features of case studies as a framework. Herreid, one of the early adopters of case studies into the science classroom, states that case studies use a narrative to help students connect science to the real world while conveying scientific content (1994). Case study classrooms are deliberately conducted so that the instructor has a facilitator role and students build knowledge together which makes group work and class discussions key pedagogical feature for case study classrooms (Herreid 1994,
In addition, a key pedagogical feature of case study design is to have students draw on prior knowledge(s) (Kim et. al., 2006). Therefore, items were designed to draw on four categories: role of the narrative, Pedagogical Features, Prior Knowledge, and Perceptions of Learning Science. If a case study experience was activating all of the key features of case studies for a student, then they would have high beliefs as measured by the scale (see Construct Map, Appendix C). Items under each of these categories were treated as sub-scales for use as variables during quantitative analysis. In addition, the sub-scale of prior knowledge was further divided to use 2 items for prior content knowledge and 2 items for prior contextual knowledge. Students were asked on a scale of 1 to 4 to agree or disagree with statements about the mule case study learning experience.

In total, 25 participants completed the BACS scale after case study exposure. Although the sample size is limited, reliability of the scale was investigated (see Appendix C for all items). The Crohbach’s alpha for the initial 28 items of the scale was .72. After dropping six items from the scale, the internal consistency increased and the Crohnbach’s alpha of .85 was determined to be acceptable and the analysis moved forward with the remaining 22 items (Table 3.1). With these final items, reliability of the sub-scales was determined. For the Role of Narrative, Pedagogical Features, and Perceptions of Learning Cronbach’s alpha coefficients were calculated as .80, .70, and .82 respectively (Table 3.1). Reliability for Prior Contextual Knowledge items and Prior Content
Knowledge items were calculated using Cronbach’s alpha as well as Pearson’s r correlations because there were only two items for each sub scale and there is some question to which test is the best fit for establishing reliability on a two-item measure (Eisinga, Te Grotenhuis, & Pelzer 2013). Reliability for the two Prior Content Knowledge was questionable at .61, however the correlation was significant at .437, p<.05. Reliability for the two Prior Contextual Knowledge items was poor at .50 and no significant correlation was found between the items. Use of these items for the measurement of prior knowledge variables proceeded with caution and are part of the limitations of this study. Analysis under RQ4 (CH 4.8, Table 4.8) proceeded for Prior Content Knowledge because there was another measure of prior content knowledge available (meiosis pre-test) but analysis using Prior Contextual Knowledge as a control variable to address RQ4 was cancelled. Interpretation using the Prior Contextual Knowledge variable in this study was heavily considered with the qualitative strand. All use of the variables generated from these two-item scales in the analysis of this study carry limitations due to these reliability issues.
Table 3.1 Subscales and reliability of subscales for the BACS scale.

<table>
<thead>
<tr>
<th>Sub-scales and Items</th>
<th>Sub-scale Reliability</th>
<th>Mean Item Score (SD) N=25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Role of the Narrative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The story helped me remember the scientific content.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The story kept me interested in the scientific topics.</td>
<td></td>
<td></td>
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<tr>
<td>I liked the story.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The story made me want to learn more about biology.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The story helped me connect the science topics to the real world.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The story was boring.</td>
<td>α = .80</td>
<td>3.28 (.38)</td>
</tr>
<tr>
<td>Having a story to follow helped me learn about meiosis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Having a story to follow helped me stay interested during class.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pedagogical Features</strong></td>
<td></td>
<td></td>
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<tr>
<td>During the case study, I liked that the professor had us do a lot of the talking.</td>
<td></td>
<td></td>
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<tr>
<td>During the case study, I liked working in groups.</td>
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<td></td>
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<tr>
<td>During the case study, I liked having class discussions with my peers.</td>
<td></td>
<td></td>
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<tr>
<td>I would rather have worked alone on the case study problem.</td>
<td></td>
<td></td>
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<tr>
<td>I liked having a problem to solve during the case study (i.e. Who was the daddy?).</td>
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<td></td>
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<tr>
<td>The class discussions distracted me from learning the scientific concepts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I didn’t trust what my peers discussed in class (the answers they came up with).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>α = .70</td>
<td></td>
<td>3.24 (.32)</td>
</tr>
<tr>
<td><strong>Prior Knowledge (Type)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I knew about meiosis before the case study. (Content)</td>
<td>α = .61</td>
<td>r = .437. p≤.05</td>
</tr>
<tr>
<td>The types of concepts in the case study were familiar to me (cell division, karyotypes, homology). (Content)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I knew about mules or horses or donkeys prior to the case study. (Contextual)</td>
<td>α = .50</td>
<td>r = .308, NS</td>
</tr>
<tr>
<td>I was able to relate to the story. (Contextual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 items</td>
<td></td>
<td>2.51 (.49)</td>
</tr>
<tr>
<td><strong>Perceptions of Learning</strong></td>
<td></td>
<td></td>
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<tr>
<td>I learned a lot of biology through the case study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think case studies are a good way to learn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The case study helped me connect biology to the real world.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>α = .82</td>
<td></td>
<td>3.28 (.46)</td>
</tr>
</tbody>
</table>

3.3.3 Situational Interest

Situational Interest was measured in this study using a modified version of a situational interest scale developed by (Linnenbrink-Garcia et al., 2010). The scale contains 12 items that measure the maintenance of situational interest (MSI) and 5 items that measure the triggering of situational interest (TSI). On a 5-point Likert scale, students were asked to agree or disagree with MSI items such as “I think what we are studying in this biology course is useful for me to know” and “I find the content of this course personally meaningful” and TSI items such as “The case studies in this class are very interesting” and “I enjoy the working through the mule case study”. (See Appendix B for all items).

3.3.4 Transfer of Knowledge Exam Question

A near transfer question was created for the mid-term exam in the course that would pertain directly to the content learned reading and interpreting karyotypes during the case study. For this study, the definition of transfer used was the “process of using knowledge or skills acquired in one context in a new or varied context” (Alexander and Murphy, 1992). Figure 3.2 shows the question as it appeared in the mid-term exam whereas the knowledge and skills acquired in mule/horse context are transferred to a new context: the human body (Alexander & Murphy, 1998). The instructor scored the question out of 5 points as follows: 1 point each for a correct answer on part a and b; 1 point for correct answer on c with 2 points for a valid explanation. The
instructor’s own discretion was used to give full or partial credit for the explanations in part c.

Consider the karyotype of a human somatic (body) cell to answer the following questions:

a) How many chromosomes are in this karyotype?

b) How does this karyotype differ from a normal karyotype?

c) What do you think the sex of this individual is? Explain your answer.

Figure 3.2 The near transfer question to measure learning of content specific to the case study.

3.4 Think-a-loud Interview Procedure (Qualitative Data Collection)

Students were asked to participate in an interview while they reviewed the case study with the researcher. Participants for the interviews were solicited by a volunteer sign-up sheet by the instructor 2 weeks after the case study was used as a normal part of the course curriculum where cell division topics would be covered. This procedure was used to ask students interview-type questions about their case study experience and also to re-visit the case study and explain what they were doing or thinking during different aspects of the case study (see Appendix A for interview prompts). This aligns with the think-a-loud method which is a more direct method to gaining understanding of problem solving processes (Van Someren, M. W., Barnard, Y. F., & Sandberg, J. A. C., 1994). This method was chosen so that the students could relive the problem solving
aspects of the case study and not just provide a recollection of how they solved the case study. It also allowed to directly probe students on what prior knowledge they had and how they approached a particular moment in the case study that may have been difficult (for example the karyotyping). To accomplish this type of data collection, the case study materials were loaded onto a tablet (iPad) using an app (Explain Everything) that can record audio (and drawing) while students revisited the case study content (narrative, figures, discussion prompts) exactly how they experienced it in class. A total of 9 students participated in a think out loud interview.

3.5 Quantitative Analysis

To explore relationships between quantitative variables, simple and partial correlations (Pearson’s r) were performed using SPSS statistical software. The linearity assumption was checked by examining scatter plots. Strength of relationships were valued as: >.3 weak, >.5 moderate, >.7 strong (Cohen et. al, 2013) and due to small sample size, 95% confidence intervals were calculated using Microsoft Excel to transform Pearson’s r into Z scores. For Pearson correlations, interval variables are assumed, and in this study not all variables are interval which could lead to overstated results. Therefore, caution was taken when interpreting the quantitative relationships and priority was also given to the qualitative wave to explain any significant relationships.
A matched pair t-test was performed on the pre and post concept inventory scores. There was missing data for one pre-test and the case was dropped from the analysis.

3.6 Qualitative Analysis

The qualitative data collected during the think out loud interviews were transcribed into Microsoft Word documents and then imported into NVivo software for deductive analysis using thematic coding and focal scale coding (Castro et al., 2010). Themes for the coding included the key variables and concepts from the framework of this study and the variables that were measured quantitatively: situational interest, role of the narrative, and pedagogical features (See Appendix D for all codes). A dichotomous scale was created for frequency scale coding to dimensionalize data for the themes of prior knowledge and conceptual understanding. For prior knowledge, data was coded as contextual or content and then frequencies were determined by tallying the mentions confirming or denying prior knowledge. Similarly, for conceptual understanding, frequencies were calculated based on accurate or inaccurate responses (Castro et al., 2010). The researcher was the sole rater for both the thematic coding and frequency scale coding.
CHAPTER 4
FINDINGS

4.1 Findings Overview

Sources for the data in this study, under each concept and construct investigated, had both quantitative and qualitative measures (see Chapter 3, Figure 3.3.1). Data are presented first for each variable in sections 4.3 through 4.7 and then finally, relationships between variables are presented in section 4.7.

4.2 Research Questions

The following research questions guided this study and data were collected and analyzed in order to address each question. The codes RQ1 – RQ5 will be used to describe the data that was collected and analyzed for each question below:

- **RQ1**: How does prior content knowledge impact student learning meiosis with case studies?
- **RQ2**: How does prior contextual knowledge impact student learning meiosis case studies?
- **RQ3**: What kind of prior knowledge helps students maintain situational interest in the case study classroom?
- **RQ4**: How do case studies (role of narrative and pedagogical moves) help students maintain situational interest in the absence of prior content knowledge?
- **RQ5**: To what extent do all four of these variables (contextual prior knowledge, content prior knowledge, the role of the narrative, and pedagogical moves) impact learning with case studies (note: on a conceptual level not a statistical level)?
4.3 Results of the Belief’s About Case Studies (BACS) Scale

Directly after exposure to the case study about a mule giving birth, students took the BACS scale. Measures from this instrument were used to generate the following variables to address the research questions for this study: Role of the Narrative (RQ4, RQ5), Pedagogical Features (RQ4, RQ5), Perceptions of Learning (RQ1, RQ2, RQ5) Prior Content Knowledge (RQ1, RQ3, RQ5), and Prior Contextual Knowledge (RQ2, RQ3, RQ5). The overall mean item score for the sample population was 3.1 (SD=.31) on a 4 point scale. Figure 4.1 shows the mean item scores for the sub-scales. Prior knowledge (contextual and content items) received the lowest scores (M=2.51 SD=.49) compared to the role narrative (M=3.28 SD=.38), the pedagogical features (M=3.24 SD=.32), and perception of learning (M=3.28 SD=.46) sub-scales. The sub-scale categories also served as themes for the qualitative data analysis. Figure 4.3 also shows examples from the qualitative wave that illustrate each of these variables. Prior knowledge items received the lowest overall scores and student explanations reflected that there were varying levels of prior content knowledge in the sample population.
4.4 Varied levels of prior content and contextual knowledge

In this study, prior content knowledge was also measured using 10 items from the Meiosis Concept Inventory (Kalas et al., 2013) in order to address RQ1, RQ3, and RQ 5. Student scores on the pre-test were low with a mean score of 12.7% out of 100%. The BACS prior knowledge sub-scale result corroborates this similarly low score in that students self-reported low prior content and contextual knowledge via BACS items in contrast to higher sub-scale scores for the other variables measured by BACS. In addition, students were prompted during the interviews as to whether or not they knew about meiosis and karyotypes (prior content knowledge) and also if they knew about mules or farm animals (prior contextual knowledge) prior to the case study. Table 4.1 shows a summary of the frequency scale coding of their responses with illustrative examples.
When prompted about prior content knowledge, students reported varying levels of prior content knowledge (56% confirmed, 44% denied). Whether students had prior knowledge of meiosis or karyotypes, they reported that they still had a positive learning experience with the case study. When students reported that their groups were mixed in levels of meiosis and karyotype prior knowledge they explained how this led to being able to work through the case study. For example, one student without any prior knowledge explained that he had to work harder both within the group and then later outside of class where he “googled”, however he was able to function in the group because a more seasoned peer helped lead the group and provided explanations to the novice students in the group (see Table 4.4, quote from S8). And when a student possessed more prior knowledge than other group members, they too explained a positive learning experience in that their own learning was re-enforced through teaching other novice group members (see Table 4.1, quote from S5). These accounts emphasize that the extent to which prior content knowledge played a role in this research context was through small group work.

Frequencies for contextual knowledge about the case study also varied in the student accounts (44% confirmed, 56% denied). When asked about their prior contextual knowledge, students who reported knowing something about farms or animals, or mules in particular, described this knowledge as leading to their interest in the case study. For example, one student knew that a mule was the offspring of a horse and donkey prior to the case study. The possibility that the case study might reveal how that conception is possible, he believed, led to his learning (see Table 4.4, quote from S5). At the same time, students who reported they had no prior knowledge of farms or mules, still found the story relatable and therefore interesting. For example, one
student felt that even though he had no personal experience with farms and animals, he knew people who did and this he found interesting (see Table 4.1, quote from S5).

In summary, when students discussed their prior content knowledge, they illustrated that level prior content knowledge impacted group work (Table 4.1, Figure 4.1). When they discussed contextual knowledge, the emphasis was placed on personal (not group) impact, namely their own interest in the story and this was true even when they had no direct contextual knowledge of mules or farms but simply could relate to others who may.

Table 4.1: Frequency Coding of Prior Knowledge

<table>
<thead>
<tr>
<th>Dimension of Code</th>
<th>Frequency (% Participants, N=9)</th>
<th>Explanatory Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirms prior knowledge (meiosis, karyotypes)</td>
<td>56%</td>
<td>S5: So I think I was the only one with the knowledge about karyotypes in my group. But which is good because, um, different people from the group can bring up different knowledge and if, say just happened to have more knowledge than you about karyotype, then it works. R: did you find yourself being a teacher to them? S5: a little bit, yeah, a little bit. R: Yeah? How did that feel? S5: um, it made me feel very, um, confident but at the same time, it kind of, uh, because I’m trying to teach them, I’m thinking more and more. So, it’s like engraving into my head.</td>
</tr>
<tr>
<td>Denies prior knowledge (meiosis, karyotypes)</td>
<td>44%</td>
<td>S8: It was hard. I had to kind of lean to my group for the majority of it and whatever I didn’t really understand, I kind of went back to my dorm room. I googled...Uh, we ended up—one person in our group actually knew karyotype, like, graphs, and they’d done a bunch of them, like, I think he’s a junior now. So, and I’m a freshman, so, it was totally new to me but, like, besides high school, I saw it once or twice but, um, he ended up, not doing it for us, but he ended up showing us like how it</td>
</tr>
</tbody>
</table>
works and basically saying like, “this ties into this,” and, like, that’s kind of what we went off of his knowledge.

<table>
<thead>
<tr>
<th>Confirms prior contextual knowledge</th>
<th>44%</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4: Well, I knew with the mule that, it has to be reproduced from a horse and a donkey so.. R: Okay, so you knew what a mule was? S4: yeah. R: did you that they were sterile? S4: No, not that part. R: Did that help you stay interested? S4: Well, I wanted to know how...how it (the conception) happened (laughs). That’s the thing that helped me learn so much.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Denies prior contextual knowledge (veterinarians, farm animals)</th>
<th>56%</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5: At first, it was very, um, very intriguing because, um, I didn’t expect her to bring up, like a story, that’s so relatable. I mean, not that I have any, um, relation to like any farms, animals, but, like, it’s just very applicable, you know? I have friends who have farms and what if that happened to them. So it-it- was very interesting and that was my first thought.</td>
<td></td>
</tr>
</tbody>
</table>

4.5 Situational Interest

Situational Interest was measured in this study using a modified version of a situational interest scale developed by (Linnenbrink-Garcia et al., 2010) to address RQ3, RQ4, and RQ5. The scale contained 12 items that measure the maintenance of situational interest (MSI) and 5 items that measure the triggering of situational interest (TSI). The survey was administered directly after the case study was concluded. Average item score for all items was 4.3 (SD=.69) on a scale of 5.

Interview transcripts were examined for evidence of situational interest. Table 4.2 shows the definitions and illustrative examples for codes under the theme of situational interest. Data were coded for the triggering of situational interest when they described that the story, characters, and dilemma stimulated learning processes such as paying attention or wanting to know more. Out of the 9 participants, 7 gave interview
answers that were coded as triggered situational interest. Students described the story or the story characters as grabbing their attention at the start of the case study (see Table 4.2, quote from S4). Students also discussed the surprise nature of an instructor launching into a narrative rather than a lecture (see Table 4.2, quote from S2). In these ways, the story as well as the instructor’s role as storyteller, served as a trigger of their situational interest.

Data were coded for the maintenance of situational interest when students describe staying engaged (paying attention, participating, persisting) with the learning due to the case study. Of the 9 students interviewed, 6 gave explanations that were coded as maintained situational interest. Students described moments in the case study where they persisted and kept working despite the challenging content the case study presented (see Table 4.2, quote from S5). During the difficult parts of working with data and looking at primary literature figures, students were able to stay engaged because they wanted to get back to the story and solve the mystery (see Table 4.2, quote from S6). Emphasis was placed on the case study as the reason for staying engaged by comparing it to other teaching modalities such as lecture (see Table 4.2, quote from S5).
### Table 4.2: Situational Interest

<table>
<thead>
<tr>
<th>Code</th>
<th>Triggers Situational Interest (7/9 participants)</th>
<th>Maintains Situational Interest (6/9 participants)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>The story, characters, and dilemma stimulate learning processes such as paying attention or wanting to know more.</td>
<td>Students describe staying engaged (paying attention, participating, persisting) with the learning due to the case study.</td>
</tr>
<tr>
<td><strong>Illustrative Examples</strong></td>
<td>S4: The title got me. R: Just the “Who’s your Daddy?” S4: Yeah I was like, “Oh well is this going to be a person, an animal?”...And I mean I didn’t lose any interest...It’s like having animal Jerry Springer at 8 o’clock in the morning (laughter)...And it was very engaging, so along with it being an 8:30 class, you know, it kinda forces you to wake up and get into the groove which is great because, um, not all the classes are like that you know? They can’t grab your attention that early because you’re just waking up and whatever.  S2: Um, usually, like, teachers will come and be like, “Oh we’re doing this today” and will just lecture. And I’m more of a like a hands-on learner so like visual things too. So when she had like the pictures on the board with it, it was like helpful....And then she made it funny- who’s the daddy? So, like, everybody was, like laughing, which make, like, the class more engaging because, usually, people are really quiet in that class. S6: {the topic meiosis} it wouldn’t be like as interesting but since, with the mule and everything, it made it a little bit easier to pay attention and be in a discussion. R: (showing slides with primary literature figures) Was it hard to stay motivated through the hard parts? S6: Honestly, no, because you wanted to get through the hard parts to get back to the story. R: What did you do when it was hard? S2: Like when this slide (primary literature slide) first came up, I was like, “well I’m in trouble now” and then she broke it down so she said like the matching numbers is the matching parts of the chromosome...she explained it pretty well. R: ...So were you still invested in solving the problem? S2: Yeah...Because we wanted to know who the daddy was. S5: ...as a whole group, we were, um, able to engage. If she taught this straight up lecture kind of thing, I might have fell asleep.</td>
<td></td>
</tr>
</tbody>
</table>
4.6 The role of the narrative and pedagogical features

The BACS scale data established the variables of the role of the narrative and pedagogical features. Students had high beliefs that the narrative played a role in their learning and that specific pedagogical features of case studies (discussion, group work, and instructor role) played a part in their learning (see Figure 4.3). To understand the extent to which these variables impact situational interest (RQ4) and learning meiosis (RQ5) interview transcripts were examined.

Table 4.3 shows the codes, definitions and illustrative examples for the role of narrative theme. When students gave examples of connecting biology to the real world through the narrative, the data were coded as ‘real world connection’. Of the 9 students interviewed, 6 gave responses that were coded as real world connection. They talked about how they were able to understand how what they learned applies to the real world and how the circumstances in the story could really happen to someone they know (see Table 4.3, quote from S5 and S8). In addition, one student made reference to the “macro” level of the animal characters while learning a “micro” level concept like cell division whereas the macro level animal is situated in real life (see Table 4.3, quote from S9).

When students attributed understanding biology concepts to elements from the narrative, the data were coded as ‘understanding biology’. Of the 9
students interviewed, 8 gave responses that were coded as understanding biology. They described that the story allows for later recall and understanding of the content. Examples were given that the story provides a back-drop with key timepoints and events to tether the learning to (see Table 4.3, quote from S5 and S7). One student even made the analogy to a song whereas the music facilitates recall of the lyric and in the case study the story facilitates recall of the content (see Table 4.3, quote from S2).

Table 4.3 Role of the Narrative

<table>
<thead>
<tr>
<th>Code</th>
<th>Real World Connection (6/9 participants)</th>
<th>Understanding Biology (8/9 participants)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Student connects biology to the real world via narrative.</td>
<td>Student attributes understanding biology concepts to the elements from the narrative.</td>
</tr>
<tr>
<td><strong>Illustrative Examples</strong></td>
<td>S5: Instead of, um, just walking out of a lecture where I’m like, “okay whatever”, it was more like, “Okay, so this is what this—meiosis and mitosis, why is it important and how can we apply it to real life?”</td>
<td>S5: I think that, as the story progresses, our knowledge also follows. So, which is really nice, and I thought it was a good way to approach it...And it actually gives like solid explanation to things that happened. Why this mule—this mule is sterile? Like what is happening? So, it was—it gave me substantial knowledge.</td>
</tr>
<tr>
<td></td>
<td>S8: we all were intrigued to learn and we were happy to learn because it was something that we could, like, it was kind of, like, a real life situation even though none of us experienced that but, like, it was something that could’ve happened to us or could've happened to one of our other relative so we understood, like,</td>
<td>S7: like if you were to say what do you remember from {a lectured format} Like, I won’t be able to like shoot it back all out, but if I had time to be like okay there was that picture of the mule and at that point we were talking about this</td>
</tr>
</tbody>
</table>
where she was coming from because it tied into real life.

S9: I can scientifically and logically follow the fact that we’re talking about cells and we’re talking about atoms and all kinds of other things, but um, when we’re talking about animals, they’re just—I know what a horse looks like, I know what a donkey looks like. I can see it happening and then it just- it makes more sense because these are animals that I can work with and interact with. Whereas the cells, I’m not even fully aware that I keep dying and regenerating all the time. (laughs) So it’s just a little cooler to me even though {cells are} still cool.

and this and then she brought the karyotype and that brought up... so it would take me time but it would give me a reference point to start recalling. So I really like that. ...And, then, like, when I went to go look back into my notes, it was really helpful having {the story}, um, like as a background...like reference points.

S2: I think it’s like reinforcing, like, it’s more of like a, like usually, you have a class and you memorize that and this kind of stuck on my mind and so I feel like I won’t forget it, it’s kind of like a song, I guess.

Table 4.4 shows the codes, definitions and illustrative examples for the pedagogical features theme. When students recognized that the instructor role is different from other learning experiences or when they described generating knowledge themselves or within groups the data were coded as ‘role of the instructor’. Of the 9 students interviewed, 6 gave responses that were coded as role of the instructor. Students took note that the instructor used a different approach during the case study that was not only different to the course but especially compared to other courses (see Table 4.4, quote from S5). When
students talked about group work as part of the learning process during the case study it was coded as ‘group work’. Of the 9 students interviewed, 8 gave responses that were coded as group work. Students reported favorably about the small group work in that it allowed them to share prior knowledge and opinions, weigh options, and form a consensus about the problems they were working through during the case study (see Table 4.4, quote from S4). Then, they were able to proceed with confidence to a whole class discussion where participation and disagreement was not a high stakes situation (see Table 4.4, quote from S7). Finally, when students described that the case study environment created a space for discourse and participation the date were coded as ‘participatory environment’. Of the 9 students interviewed, 3 gave responses that were coded as participatory environment. Students reported that the class discussions were not intimidating but rather a space to work with disparate answers and unknowns (Table 4.4, see quote S1 and S2).
Table 4.4 Pedagogical Features

<table>
<thead>
<tr>
<th>Code</th>
<th>Role of Instructor (6/9 Participants)</th>
<th>Group Work (8/9 Participants)</th>
<th>Participatory Environment (3/9 Participants)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Students recognize that the instructor role is different from other experiences they have had. Students describe generating knowledge themselves or within groups rather than it coming solely from the instructor.</td>
<td>Students attribute group work as part of the learning process during the case study.</td>
<td>Students recognize the case study environment created a space for discourse and participation.</td>
</tr>
<tr>
<td><strong>Illustrative Example</strong></td>
<td>S5: So, um, I really liked the fact that she, um, she threw, like, a question and she was like, “Okay, now you guys think”. Because, um, I think a lot of professors miss out on, um, the importance of class discussion and first thinking individually. Because, um, when she did that, um, we came up with so many different possibilities and we came up with so many different ways to approach this one problem. And then, and then, um, we brought it all together and it definitely worked on our teamwork, as well as our individual thinking because, uh, unless somebody had to bring up an idea, we couldn’t move forward. So everybody had to chip in little by little. And so I think the way she approached it, the method that she used, of how we think individually and then we bring it together as a group and then we bring it altogether as a class really worked out.</td>
<td>S4: Um, the lecture probably would’ve been a lot harder for me to, like, grasp, like, the understanding of meiosis and mitosis and, like, it’s just, like, working in a group is a lot easier because I got everyone’s opinion on it and I—kind of—everyone, like, kind of pitched in what they knew prior to and what they—like, their knowledge of the, like, the topic. So it was a lot easier to do it in a group. That’s just why I like groups because there’s just like everyone pitching in rather than just one person.</td>
<td>S1: I liked {class discussion} because we were able to come together as a group and we all had our opinions, you know, to form as far as the case study went. So I thought it was very good.</td>
</tr>
<tr>
<td>S4: ...we were like, okay it should be Lightning. Then people were saying Jake and we were like “Noooo!”</td>
<td></td>
<td></td>
<td>S2: ...we were like, okay it should be Lightning. Then people were saying Jake and we were like “Noooo!”</td>
</tr>
<tr>
<td>R: Was it hard {for your group} to stick to your choice or were you worried you had it wrong?</td>
<td></td>
<td></td>
<td>R: It’s safe to be wrong?</td>
</tr>
<tr>
<td>S2: Um, we were worried but it was like, our class—it doesn’t feel heavy. She makes the environment like very friendly</td>
<td></td>
<td></td>
<td>S2: Yeah, like in my bio class, “Oh, you don’t know the answer? You look down.”</td>
</tr>
</tbody>
</table>
| R: Okay so this was a different environment. So, even if you hadn’t—say you weren’t in the group setting, and you were like, “I think it’s
In addition to the BACS data and the interview responses, in an open-ended question at the end of the case study, students were asked what their favorite part of the case study was. Although these answers were shorter than the responses collected during the interviews above, they cover a larger stretch of the sample population’s responses and were collected directly after the case study ended. Twenty (N=20) responses were collected and organized under the two themes: Role of the Narrative and Pedagogical Features. Table 4.5 shows the direct quotes as written by the students on the open-ended question. In the majority of the responses (65%) students talked about the narrative, the characters, or the specific learning that occurred via the narrative such as learning karyotypes. In the remainder of responses (35%) students mentioned group work, class discussion, or the specific activities that took place during small group work such as looking at chromosomes. The results here, echo the findings for the think-a-loud interviews. Student’s favorite parts of the case
study were specifically linked to the narrative about the mule and also to the pedagogical features that they experienced through the mule case study.

Table 4.5 Student responses about their favorite part of the case study (N=20)

<table>
<thead>
<tr>
<th>Role of the Narrative 65% of Responses</th>
<th>Pedagogical Features 35% of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed the connection between lecture and real life, due to the fact I have horses and mules.</td>
<td>That everyone was trying to figure it out.</td>
</tr>
<tr>
<td>Trying to figure out how the mule got pregnant.</td>
<td>Doing problems that relate to the case study.</td>
</tr>
<tr>
<td>Real world application of topics not just lectures on concepts.</td>
<td>Having discussion.</td>
</tr>
<tr>
<td>Learning karyotypes</td>
<td>Being able to discuss with the rest of the class.</td>
</tr>
<tr>
<td>Learning how mating between horse and donkey can have different offspring.</td>
<td>It was interactive.</td>
</tr>
<tr>
<td>Reading the genetics and figuring out the animals' gender.</td>
<td>Looking at the chromosomes</td>
</tr>
<tr>
<td>Learning how mules can reproduce. The anticipation of finding out who the father was going to be.</td>
<td>Reading the genetics and figuring out the animals’ gender.</td>
</tr>
<tr>
<td>Learning Molly’s infant had a horse father while looking like a donkey.</td>
<td></td>
</tr>
<tr>
<td>The story kept me interested. It had a lot of angles (wasn't just surface level).</td>
<td></td>
</tr>
<tr>
<td>That we chase a mystery and could follow a very cute animal.</td>
<td></td>
</tr>
<tr>
<td>That I became attached to Molly as we tried to solve her mystery. (ex. I remembered her name.)</td>
<td></td>
</tr>
<tr>
<td>Alternating between the plot and the lecture.</td>
<td></td>
</tr>
<tr>
<td>Finding the end.</td>
<td></td>
</tr>
</tbody>
</table>
4.7 Learning Meiosis

Learning meiosis data were collected to address RQ1, RQ2, and RQ5. The BACS scale was used to measure one learning variable which was the student’s perception of their learning (Figure 4.3) and students reported a mean item average of 3.28 on a scale of 4 for this sub-scale. In addition, two more learning variables were measured using the Meiosis Concept Inventory post-test and also a near transfer question on the mid-term exam for the course. Students were given the Meiosis Inventory post-test after the case study (during final class period where case study was used). We recall, that student scores on the pre-test that was used to measure prior content knowledge, were generally low with a mean class score of 12.7% out of 100% (SD=7.8%). Post-test scores (M = 25.4%, SD = 14.7) were significantly higher than pre-test scores, t(21) = 4.31, p < .01 indicating that students learned meiotic concepts as measured by the inventory between the start and the end of the case study.

As described in Chapter 3, a near transfer question was created for the mid-term exam in the course that would measure positive transfer of karyotype concepts from the case study context (mules) to a new context (humans). Figure 4.6.1 shows the question as it appeared in the exam and the frequency of responses (N=29). The question drew directly on the karyotype activities used during the case study required students to read and interpret a human karyotype as opposed to the horse, donkey, and mule karyotypes they
interpreted during the case study. The average score (graded by the course instructor) on the 5 point short answer item was a 3.5 and the majority of students (34%) received a score of 4 out of 5 points.

![Figure 4.2 Student performance on a karyotype transfer question post-case study exposure](image)

At the end of the think-out-loud interview where students had reviewed the case study on the iPad, students were prompted to demonstrate how they would explain to a friend why mules are not sterile which is the crux of the case study narrative. The intent of this prompt was to tease out whether or not student could articulate the big picture of what they learned during the case study using accurate meiosis concepts and jargon. Table 4.6 shows the extent to
which students demonstrated an accurate or inaccurate understanding.

Students with inaccurate understanding used non-scientific jargon such as “they are unique” (see Table 4.6, quote from S8) or misuse scientific such as mutation (see Table 4.6, quote from S2) to explain why mules are technically not sterile. Students with accurate understanding were able to articulate explanations of meiotic concepts such as how mule meiosis would normally fail (see Table 4.6, first quote from S9) and how if it did proceed, what underlying biological mechanism would explain that (see Table 4.6, second quote from S9 and S3).
Table 4.6 Frequency coding of conceptual understanding after the case study.

<table>
<thead>
<tr>
<th>Dimension of Code</th>
<th>Accurate</th>
<th>Inaccurate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Student articulates accurate understanding of a meiotic concept</td>
<td>Student articulates inaccurate or incomplete conceptual understanding</td>
</tr>
<tr>
<td><strong>Frequency (% Participants) N=9</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Illustrative Example</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S9: What I said was that it just wouldn’t be able to duplicate. They wouldn’t be able to make daughter cells...yeah so Metaphase in meiosis II.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S9: So during the process of meiosis when the egg was separating, all the horse DNA went into one cell and then that one gamete, that egg, that was the one that got fertilized.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3: yeah, that they’re not necessarily sterile, they’re just most of the time sterile but it’s because of the way that the, um, chromosomes sometimes line up and it takes kind of like a swiss cheese lining of holes for it to actually happen but as long as one set of parent’s chromosomes end up in one egg, the mule gets pregnant with an animal of that species, it could be done.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S8: I don’t know how to explain it. Um, they’re considered to be sterile because, I mean, I don’t know, I feel like it’s just because like, the sense that, like, they’re unique and they just aren’t—you’re not really supposed to produce- like reproduce mules, I guess, I feel you could say, like they’re just kind of a unique species and they’re supposed to like, kind of stay that way.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2: ...because of their genetics and then how like with the sperm and the egg, um, it doesn’t always get there and then there’s like the mutation, um, so like, sometimes, it doesn’t happen often.</td>
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<td></td>
</tr>
</tbody>
</table>

4.8 The relationship between prior knowledge, situational interest, and learning in the case study classroom

Since the relationships between the above reported variables are at the center of the conceptual framework that drives this study, simple correlations were performed to address RQ1, RQ2, and RQ3. Table 4.7 shows a matrix of correlations between the measures of prior knowledge, situational interest, and
learning in this study. No correlations were performed between variables
generated from BACS sub-scales and total BACS scores because BACS sub-scales
are part of total BACS score. Strength of relationships were valued as: >.3 weak,
>.5 moderate, >.7 strong (Cohen et. al, 2013).

Meiosis pre-test scores were weakly positively correlated with both the
meiosis post-test scores $r(21)=.372, p<.05$ and the transfer question scores
$r(21)=.370, p<.05$. Prior content knowledge, as reported by the BACS items, was
moderately positively correlated with situational interest $r(21)=.477, p<.05$ and
strongly positively correlated with BACS perceptions of learning item scores
$r(21)=.727, p<.01$. Contextual knowledge, as reported by BACS items, was
moderately positively correlated with the content transfer question $r(21)=.364,$
$p<.05$ and highly positively correlated with BACS perceptions of learning item
scores $r(21)=.771, p<.01$. Situational interest was moderately positively
correlated with both BACS perceptions of learning items $r(21)=.538, p<.01$ as
well as with total BACS scores $r(21)=.570, p<.01$. Content transfer scores were
moderately positively correlated to total BACS scores $r(21)=.362, p<.05$. And
lastly, a strong negative correlation between the meiosis post-test and the
content transfer question was found $r(21)=-.509, p<.01$. These findings will be
interpreted cautiously in the next Chapter as the transfer question variable was
not interval and the correlations could be overstated. In summary, the strongest
positive correlations were found between prior knowledge (content and
contextual) and student perceptions of learning and there was also a strong positive correlation between situational interest and perceptions of learning.

**Table 4.7 The relationships between prior knowledge, situational interest, and learning variables N=22**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>.072</td>
<td>-.263</td>
<td>.037</td>
<td>.377**</td>
<td>-.370**</td>
<td>-.219</td>
<td>.032</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>.123</td>
<td>X</td>
<td>[.07, .75]</td>
<td>[.06, .69]</td>
<td>[.44, .88]</td>
<td>X***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>[95% CI reported under sig coefficients [LL, UL]]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lastly, to address RQ4, the relationships between role of the narrative, pedagogical features, situational interest, and learning variables were determined. Because RQ4 asks how these variables interact in the absence of prior knowledge, prior knowledge was used as a control variable. Partial correlations were run using the two quantitative measures for prior content knowledge as control variables: score on the meiosis inventory pre-test and the prior content knowledge items from the BACS scale. Table 4.8 shows the
relationships between the role of the narrative and pedagogical features with situational interest and learning variables controlling for prior knowledge.

Role of the narrative and near transfer question were moderately positively correlated ($r(21) = .482, p < .05$) when controlling for meiosis pre-test and when controlling for BACS prior content knowledge items ($r(21) = .422, p < .05$). These findings will be interpreted cautiously in the next Chapter as the transfer question variable was not interval and the correlations could be overstated. There was also a moderate positive relationship between pedagogical features and situational interest controlling for meiosis pre-test ($r(21) = .491, p < .05$) and a strong positive relationship between pedagogical features and situational interest controlling for BACS items prior content knowledge ($r(21) = .699, p < .01$). In summary, there is a positive correlation between the role of the narrative and learning no matter the level of prior content knowledge (reported or measured). There is an even stronger positive correlation between pedagogical features and situational interest no matter the level of prior content knowledge (reported or measured). In the discussion that follows, interpretation of these relationships will give priority to the qualitative findings to provide further explanation and also to add caution where the statistical relationship could have been overstated due to the type of variables and the nature of the parametric test.
Table 4.8 The relationship between case study variables, situational interest, and learning variables controlling for prior knowledge.

<table>
<thead>
<tr>
<th></th>
<th>Controlling for Prior Content Knowledge (Meiosis Pre-Test)</th>
<th>Controlling for Prior Content Knowledge (BACS Items)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Role of the Narrative</td>
<td>Pedagogical Features</td>
</tr>
<tr>
<td><strong>Situational Interest</strong></td>
<td>.393</td>
<td>.491*</td>
</tr>
<tr>
<td></td>
<td>[.09, .76]</td>
<td></td>
</tr>
<tr>
<td><strong>Meiosis Post-Test</strong></td>
<td>-.211</td>
<td>-.127</td>
</tr>
<tr>
<td><strong>Near Transfer Question</strong></td>
<td>.482*</td>
<td>.049</td>
</tr>
<tr>
<td></td>
<td>[.08, .75]</td>
<td></td>
</tr>
<tr>
<td><strong>Perceptions of Learning</strong></td>
<td>.333</td>
<td>.020</td>
</tr>
</tbody>
</table>

* denotes p<.05, **denotes p<.01, 95% CI reported under sig coefficients [LL, UL]
5.1 Discussion Overview

This study was guided by the following research questions:

- **RQ1**: How does prior content knowledge impact student learning meiosis with case studies?
- **RQ2**: How does prior contextual knowledge impact student learning meiosis case studies?
- **RQ3**: What kind of prior knowledge helps students maintain situational interest in the case study classroom?
- **RQ4**: How do case studies (role of narrative and pedagogical moves) help students maintain situational interest in the absence of prior content knowledge?
- **RQ5**: To what extent do all four of these variables (contextual prior knowledge, content prior knowledge, the role of the narrative, and pedagogical moves) impact learning with case studies? (note: on a conceptual level, not a statistical level)

In the discussion that follows, I will interpret the findings presented in Chapter 4 as they relate to each of the research questions. An overarching statement is made at the start of each section to provide a general interpretation of the findings for each research question followed by a discussion of the evidence and literature that supports each interpretation.

5.2 The role of prior knowledge learning meiosis during a case study (RQ1)

*RQ1 Overarching Statement*: Students who possessed expert knowledge of meiosis tended toward demonstrating expert knowledge after the case study.
They were also able to apply knowledge and skills learned in the case study to a new problem. Students who may or may not possess expert knowledge, but who had prior exposure to meiosis, believed that they learned a lot of biology during the case study.

In this study, scores on the Meiosis Concept Inventory, when used as a pre-test for prior content knowledge, were low (M=12.7% out of 100%). This means that students chose the expert answer on either 0, 1, or 2 of the 10 questions. When compared to other measures of prior content knowledge such as the BACS and the interview questions (56% reported having knowledge of meiosis and karyotypes) the low score on the meiosis pre-test is not unexpected as some students in the course had no prior exposure to meiotic concepts. But it is also worth examining the idea that even though students have some meiotic knowledge, as when they report on the BACS or interview, that this is not complete nor expert level meiotic conceptual knowledge as measured by the inventory. The design and validation of the Meiosis Concept Inventory explicitly relies on gauging novice to expert answers and the experts used in the validation were trained biologists. This means that to answer a question correctly, one must hold expert level knowledge of the concept covered by the question.

When the Meiosis Concept Inventory items were used to measure learning after the case study, there was a significant improvement in score however the scores were still low. So, it is important to underscore that the type of prior content knowledge and learning of meiosis, as measured by the instrument, is expert.
level. This becomes important when we look at learning as measured by the near transfer question.

The average score on the short answer question was 3.5 out of 5 points total with the majority of students scoring above a 4, a much better learning outcome than the Meiosis post-test. Incidentally, per the instructor, this is a similar performance on this item as she sees in her upper-level biology courses.

At any rate, the possession of expert knowledge partially explains student’s performance in the case study classroom when learning is measured as expert level knowledge or ability to transfer knowledge to a new context. This aligns with what is known about prior content knowledge in educational settings in that prior content knowledge has a positive effect on performance in many educational settings (Dochy, Segers, and Buhl, 1999) and specifically in the PBL setting (Schmidt, Rotgans, and Yew, 2011). It also confirms what was observed in a preliminary study about case study pedagogy in that prior content knowledge was an indicator of final grade in a course taught solely with case studies (Hunter, 2013 unpublished data).

The quantitative relationships reported here tell part of the story, but we are left asking to what extent does prior content knowledge play a role in the case study classroom? And further, what else could account for learning meiosis with the case study when prior content knowledge is not present? From the qualitative strand we find that students who reported not having had exposure
to meiosis or karyotypes learned from their more expert peers during the small
group discussions. For example, when students talked about lacking prior
content knowledge, they articulated that others in their group did have prior
content knowledge. They pointed to the idea that progress could continue with
the case study because as a group they were able to share knowledge and
continue the work. Those who did have prior knowledge of meiosis and
karyotypes also confirmed that they acted in a teaching role during group work
and that this was a positive experience for their own learning. In this way, prior
content knowledge served in a moderating role through a feature of the
pedagogy, namely small group work. Those who lacked prior content knowledge
stayed invested in the learning because the group work provided an opportunity
for more expert students to share knowledge with novice students. Remarkably,
the subset of students interviewed in this study all participated within a group
that, by their account, had stratified levels of prior content knowledge.
Therefore, in this study context, small group work acted to moderate how the
level of prior content knowledge manifested during the case study.

5.3 The role of contextual knowledge on learning meiosis during a case
study (RQ2)

_overarching statement_: Students who related to the story and characters
tended toward believing they learned a lot of biology from the case study and
also toward applying knowledge and skills learned in the case study to a new
problem.
This study also sought to isolate the role of prior contextual knowledge in the case study environment. For this study, the particular manifestation of prior contextual knowledge was constrained to knowledge related to the narrative which has also been explored as ‘problem familiarity’ in the PBL literature (Sockalingham & Schmidt, 2013). Students were asked two BACS items that were used to measure prior contextual knowledge: whether the types of characters in the story were familiar to them (animals, farmers, veterinarians) and whether they could relate to the story.

Much like prior content knowledge reported above, prior contextual knowledge had a strong positive relationship with student’s perceptions of their learning. More interesting though, is that prior contextual knowledge as measured by BACS, but not prior content knowledge as measured by BACS, had a significant positive relationship (although weak) with performance on the near transfer question. This means that student’s familiarity with the story (its characters and its relevance) partially explains their ability to transfer a skill (reading karyotypes) that was embedded within the narrative of the case study to a new context. And, these relationships are not significant for the other learning outcome of the meiosis inventory post-test (expert level content knowledge). This relationship is specific to the context (here the case study) specific content knowledge.

The way that this relationship works remains unclear. The conceptual framework for this study suggested that a potential role for contextual
knowledge would be to help students maintain interest in the case study classroom (Chapter 1, Figure 1.2). And when students discussed their contextual knowledge, they discussed it as a component of what was interesting about the narrative.

Student’s explanations for the role of contextual knowledge centered around their own personal response the narrative. Students that confirmed they had contextual knowledge indicated that this led to an immediate and early moment in the case study where they were interested in the story. However, even those who claimed not to have any personal knowledge or experience with mules, horses, or farms still felt the story was relatable. In PBL, problem familiarity is scrutinized as a potential for a better learning outcome because if students know a little about what is being talked about or asked in the problem they may be more likely to succeed in solving it (Sockalingham & Schmidt, 2013). However, in case study pedagogy, the narratives are much more robust than in PBL problems. The pedagogy strongly prescribes a storytelling aspect where the narrative moves the teaching and learning along (Herreid, 2005). In this particular case study, an interrupted case study, the narrative unfolds with multiple characters, layers of information revealed, and next questions to answer. Perhaps there is something much more universal to characters in a story—any character in any type of story—that qualifies to be relatable and familiar to anyone just as the students explained during the interviews. It is possible that for case study pedagogy, contextual knowledge need not be limited
to specific knowledge about the persons, places, or things the story includes but rather just the overall relatability to storytelling in general. There was no quantitative relationship found between prior contextual knowledge (RQ3 further discussed below) and situational interest as the framework predicted, however the findings above offer some support that there is a link between relating to the narrative and positive learning outcomes.

However, this interpretation must be treated very tentatively because of the questionable reliability of the two-item scale for contextual knowledge (see CH 3, section 3.2.2). A limitation of this study is that only one manifestation of prior contextual knowledge was used and at that it was a two-item scale in which reliability could not be established. It is possible that these two items were not context specific enough to demonstrate a relationship. Because of this, only the measures of prior content knowledge were used to answer RQ4 below and prior contextual knowledge was dropped from the analysis for RQ4.

5.4 The role of prior knowledge in maintaining situational interest (RQ 3)

*Overarching Statement: Students who had prior meiosis exposure tended toward being interested and staying interested in the class topics, the case study, and the instruction throughout the case study.*

The conceptual framework of this study aligns with the case study pedagogical dogma of “start with a story” (Herreid, 2006) in that the narrative serves as a trigger of situational interest for the audience. But, then the next
question becomes what happens to that situational interest? Ideally, in any learning environment, the goal would be for students to maintain their situational interest so that they may continue to engage in meaningful behavioral and cognitive activities that lead to learning the material at hand. Research has demonstrated that prior knowledge has a relationship with situational interest (Tobias, 1994) and what’s more, case study pedagogy aims to deliberately draw on prior knowledge.

There was a significant relationship between prior content knowledge and situational interest, but not contextual knowledge. There was some suggestion of a role for prior contextual knowledge in maintaining interest through the qualitative strand (discussed above RQ2). However, there was a clear explanation for the role of prior content knowledge in learning provided by both the quantitative relationships and the student explanations (discussed above RQ1). Adding to this support is the significant relationship between prior content knowledge and situational interest in this study context. When taken together, the evidence for RQ1 and RQ3 provides a new framework for the role of prior content knowledge in this research context. Figure 5.1 shows a visual representation of this interpretation using both the quantitative and qualitative strands pertaining to RQ1 and RQ3.

In summary, a positive relationship was found between prior content knowledge and situational interest. In addition, student explanations about how prior knowledge impacted the learning experience revealed a role for small
group work in moderating the impact that the level of prior knowledge had in the case study environment. Figure 5.1 illustrates a specific role for prior content knowledge within the framework for case study pedagogy presented in this study. Because this study did not control for individual interest as students entered the course or the case study context, it is not possible to discern what part of maintaining interest is due to individual interest and what part is situational to the case study context.

Figure 5.1: Prior content knowledge helps students maintain situational interest in the case study classroom.
5.5 The relationship between case studies (the role of the narrative and pedagogical features) and situational interest in the absence of prior content knowledge (RQ 4)

**Overarching Statement:** Student’s with strong positive feelings about the pedagogical moves (group work, discussions, teacher as facilitator) tend toward maintaining situational interest no matter what their level of prior content knowledge.

Student’s that feel strongly that the narrative plays a role in their learning tend toward applying knowledge and skills learned in the case study to a new problem no matter what their level of prior content knowledge.

While addressing RQ1 and RQ3, evidence emerged about the role of a particular pedagogical feature of case studies: group work and discussions. The framework that guided this study suggested a potential role for the robust set of pedagogical features that could serve to mediate the lack of prior content knowledge in the case study classroom (Figure 1.2). To investigate this, the role of the narrative and pedagogical features were realized as individual subscales and therefore individual variables for quantitative analysis. The teasing out of these two sub-categories originated through the literature that describes the design and deployment of case studies as well as the specific development of the mule case study to contain both a rich narrative and utilize all features of case study pedagogy that have been emphasized in the literature: instructor as facilitator and use of discussion (small group and class) (Herreid, 1994, Herreid,
2006, Kim et al., 2006). Items on the BACS scale mapped to each of these sub-categories and students reported overall high positive beliefs that the narrative had a role in their learning (M=3.28 out of 4) and that the group work, class discussions, and the instructor as facilitator had a role in their learning (M=3.24 out of 4) (see Figure 4.1).

More specific to RQ4, there was a positive relationship between beliefs about the pedagogical features and situational interest controlling for both prior content knowledge as measured by the concept inventory (r(21)=.476, p<.05) and an even stronger relationship when controlling for student-reported prior content knowledge (r(21)=.699, p<.01). This was not true for beliefs about the role of the narrative. However, looking further downstream at learning variables, there was a moderate relationship between beliefs about the role of the narrative and learning meiosis as measured by the transfer question controlling for prior content knowledge as measured by the concept inventory (r(21)=.476, p>.05) and controlling for self-reported prior knowledge (r(21)=.422, p<.05).

To further understand these relationships, the qualitative strand provides explanations of how these variables may be associated in the research context. Although there was no quantitative relationship found between role of the narrative and situational interest, students attributed behaviors and activities that are indicators of situational interest (paying attention, participating, and persisting to work through difficult material) to learning the end of the story.
(specifically, who was the mule’s sire). When prior content knowledge is controlled for, a direct relationship between the pedagogical features and situational interest is strong. Students described the instructor’s role as a facilitator rather than a lecturer as a key factor in their learning. They explained that they were allowed to think and discuss what they knew or did not know and come up with their own ideas. Similarly, they described both the discussions they had in small groups or as a whole class as a key component to their learning because they were able to build knowledge with peers. This aligns with the constructivist theory that case study pedagogy is built on in that the learner brings own ideas, knowledge, and attitudes to the learning situation and connects new to old (Jonassen, 1999).

In summary, these findings describe the ways in which case study pedagogy facilitates learning through two distinct mechanisms. First, through engaging with a rich and interesting narrative, students are able to acquire knowledge that they are then able to transfer to other contexts. This is similar to PBL classrooms where attention is given to elaborating knowledge through the problem context and this elaboration leads to long term retention and transfer of knowledge (Dochy, F., Seagers, M., Van den Bossche, P., & Gijbels, D., 2003). Second, through specific pedagogical features like small group work and class discussion, students maintain their interest which then leads to learning. And this is true whether students have prior content knowledge or not. This is not surprising because the interest literature describes novelty as a trigger of
interest (storytelling, getting into groups rather than lecture) (Hidi, S., & Renninger, K. A., 2006) and then specific classroom activities as vehicles for maintaining situational interest (Rotgans, J.I, & Schmidt, H.G., 2011)

Previously, a mechanism was demonstrated to explain why and how lacking prior content knowledge can still lead to successful learning outcomes in this research context (RQ1 & RQ3 above). Together, these findings support a new framework for learning through case study pedagogy and this will be discussed in relation to the final research question (RQ5).

5.6 The role of prior knowledge, situational interest, and case studies in learning meiosis (RQ5)

Overarching Statement: The case study about a mule employs a set of pedagogical features and an interesting narrative that interacts with prior knowledge to aid in the maintenance of situational interest and that also leads to learning meiosis.

A revised framework for the role of prior knowledge, situational interest, and case study pedagogy in the undergraduate biology classroom is shown in Figure 5.2. This study has demonstrated the ways in which case studies employ a rich narrative and specific pedagogical features that trigger situational interest and also help students maintain interest whether or not they possess prior content knowledge.
As students begin to work with a case study, their situational interest is triggered by the hook of the narrative or the role of the instructor as storyteller (see Table 4.2). Having prior content knowledge is a part of situational interest and subsequent success with case studies, however it is not the only path to learning with case studies. Students without prior content knowledge are able to continue with the case study through small group work with peers who have prior content knowledge (see Table 4.1). Further, whether or not they have prior content knowledge, the narrative facilitates learning meiosis (see Table 4.8 and Table 4.3) by helping students connect biology to the real world (see Table 4.3 and 4.6.3). This is also true for pedagogical features. No matter if students have prior content knowledge, they can still maintain their interest through their engagement with small group work, having the instructor serve as a facilitator of knowledge, and by feeling that the classroom is an inviting, participatory environment (see Table 4.4 and 4.6.3). The rich narrative of the case study can also lead to behaviors such as paying attention and persisting through difficult content which are indicators of maintaining situational interest (see Table 4.2). In this study context, situational interest was strongly indicative of student’s overall positive beliefs and feelings about their learning with the mule case study (see Figure 4.1 and Table 4.7) and these beliefs were strongly related to students ability to transfer knowledge that they learned through the case study to a new context (see Table 4.7).
5.7 Implications for teaching and developing case studies

The purpose of this study was to investigate the role of prior knowledge, situational interest, and case study pedagogy on learning in the case study educational context to better understand how to develop case studies and train faculty to deploy and assess case studies in their classrooms. The following are important outcomes of this study that translate directly into best practices for case study pedagogy:

1) Content knowledge at varying levels from expert to incomplete are related to situational interest and learning. Case studies should be developed that allow students to draw on prior knowledge and that allow students to share prior knowledge with each other through small group work.
2) Attention should be payed to developing rich narratives and instructors should embrace the role as a storyteller and facilitator of knowledge by using the narrative during class. These narratives should have the concepts and content that students are meant to acquire embedded within the narrative and these narratives should create connections between these concepts and the real world.

3) Key pedagogical features must be deployed during the case study in order for the pedagogy to maintain its robust facilitation of learning. These key features are small group work, the instructor as facilitator of knowledge, and the opportunity for larger class discussion so that students may experience a participatory environment.

4) Instructors should pay attention to the prior knowledge composition of small groups to ensure that there is variability in groups. Instructors should also assess case studies using an instrument like BACS to confirm if a case study is functioning and to improve on the case study between uses.

5.8 Study Limitations

A major limitation of this study is the small sample size. Replication studies will be necessary to confirm findings and any generalizations of the findings here must take into consideration the small sample size and the research context (non-majors biology course at a public university). As with most classroom
research designs, the instructor may be a confounding variable and in this particular research context the instructor was well-liked and she was adept at deploying active learning pedagogies. This instructor had made use of group work and class discussions prior to the deployment of the case study. Although this study was mixed methodological and had multiple manifestations for each concept, other manifestations could have provided a more accurate understanding. For example, situational interest was measured by survey and through qualitative interviews after the participants experienced the case study. This limits the strength of the conclusions drawn here and future research could include videotaping or classroom observation for indicators of situational interest during the case study. Similarly, this would help address trustworthiness by triangulating the multiple sources for the qualitative data. Trustworthiness was not established in this study and in future studies triangulation of data sources and an additional coder for the qualitative data would address this limitation. In addition, the level of individual interest students had coming into the class and the case study context was not measured or controlled for. Therefore, it was not possible to know whether their level of interest was a result of their already high level of interest.

5.9 Further Research

Further research should include repeating the present study design in different research contexts with larger sample sizes. In addition, additional manifestations of prior content knowledge, situational interest, and learning
should be explored. For example, additional and different types of transfer questions for learning meiosis concepts could be used as well as group work observations for evidence of situational interest.
A. IRB DOCUMENTATION

Sample text for an Institution with a Federally Assured (FWA) to rely on the IRB/IEC of another institution (Institutions may use this sample as a guide to develop their own agreements).


Name of Institution or Organization Providing IRB Review (Institution/Organization A):

IRB Registration #: 10183 Federalwide Assurance (FWA) #, if any: FWA 00014746

Name of Institution Relying on the Designated IRB (Institution B):
University of Massachusetts at Amherst

FWA #: 00003909

The Officials signing below agree that University of Massachusetts at Amherst may rely on the designated IRB for review and continuing oversight of its human subjects research described below: (check one)

( ) This agreement applies to all human subjects research covered by Institution B’s FWA.

( ) This agreement is limited to the following specific protocol(s):

Name of Research Project: "The role of prior knowledge, situational interest, and case studies in the undergraduate biology classroom"

Name of Principal Investigator: __________________________

Sponsor or Funding Agency: __________________________ Award Number, if any: __________________________

( ) Other (describe): __________________________________________________________

The review performed by the designated IRB will meet the human subject protection requirements of Institution B’s OHRP-approved FWA. The IRB at Institution/Organization A will follow written procedures for reporting its findings and actions to appropriate officials at Institution B. Relevant minutes of IRB meetings will be made available to Institution B upon request. Institution B remains responsible for ensuring compliance with the IRB’s determinations and with the Terms of its OHRP-approved FWA. This document must be kept on file by both parties and provided to OHRP upon request.

Signature of Signatory Official (Institution/Organization A):

[Signature]

Print Full Name: Todd Regn

Institutional Title: Executive Director, Research & Sponsored Programs

Signature of Signatory Official (Institution B):

[Signature]

Print Full Name: Jennifer A. Donais

Institutional Title: Assistant Vice Chancellor for Research and Engagement, Compliance and Research Support Services

Date: 10.27.16

Date: __________________________

Digitally signed by Jennifer A. Donais

Date 2014.10.21 11:59:31 -05'00'
B. STUDY INSTRUMENTS

Meiosis Pre-Test

Name: ________________________________________

Z number: _____________________________________

Directions:

The purpose of this survey is to measure how much you know about meiosis. The data collected from this survey will help researchers understand how students learn from case studies. Therefore, it is important for you to answer honestly and that you complete the entire survey.

This is not a test. Your answers will remain anonymous and will not be used as part of your grade for the course.

Please circle the correct answer and write down any thoughts you might have on how your arrived at your answers.
Question 1

SELECT THE SINGLE BEST ANSWER

One of the characteristics that differentiates all haploid cells from all diploid cells is that

a) haploid cells have half as many chromosomes than diploid cells.

b) haploid cells have one full set of chromosomes while diploid cells have two.

c) haploid cells’ chromosomes have a different structure/shape from diploid cells’ chromosomes.

d) haploid cells have half the amount of DNA as diploid cells.
Question 2

SELECT THE SINGLE BEST ANSWER

A certain cell is diploid and has a total of six chromosomes. If we pretend that its chromosomes remain condensed throughout the cell cycle, which of the diagrams below correctly represents the chromosomes of this cell before DNA replication?

a)  

b)  

c)  

d)  

a)  b)  c)  d)
If we pretend that chromosomes remain condensed throughout the cell cycle, what notation best describes the cell pictured below?

a) n=2 (haploid with two chromosomes)
b) n=3 (haploid with three chromosomes)
c) 2n=6 (diploid with six chromosomes)
d) 3n=6 (triploid with six chromosomes)
Question 4

SELECT ALL THE ANSWERS THAT APPLY

One or more of the cells represented below are haploid. Which one is it/which ones are they?

a)  

b)  

c)  

d)  

One or more of the cells represented below are diploid. Which one is it/which ones are they?

SELECT ALL THE ANSWERS THAT APPLY

a)  

b)  

c)  

d)
A diploid plant of interest has a total of two chromosomes per (somatic) cell, and its genotype is $AaBbDd$. If we pretend that chromosomes remain condensed throughout the cell cycle, which of the diagrams below could represent a cell that contains the two chromosomes of this plant?

a)  

b)  

c)  

d)
Question 7

SELECT ALL THE ANSWERS THAT APPLY

Sometimes chromosomes are represented like X's or like in the picture on the right. This picture represents a

a) chromosome composed of two sister chromatids.
b) chromosome that has undergone DNA replication.
c) chromosome in its diploid state.
d) pair of homologous chromosomes.
In a eukaryotic cell, DNA replication results in an increase in the

a) amount of DNA in that cell.

b) number of chromosomes in that cell.

c) number of DNA molecules in that cell.

d) ploidy of that cell (e.g. from 2n to 4n).
SELECT ALL THE ANSWERS THAT APPLY

The object represented below is composed of

a) four single-stranded DNA molecules.
b) one double-stranded DNA molecule.
c) two double-stranded DNA molecules.
d) two single-stranded DNA molecules.
Question 14

SELECT ALL THE ANSWERS THAT APPLY

Which of the following events occur during prophase of meiosis I?

a) Crossing over of homologous chromosomes.

a) Lining up of homologous chromosomes in the centre of the cell.

a) Pairing of homologous chromosomes.

a) Replication of most of the chromosomal DNA (formation of sister chromatids).
### Modified Situational Interest Scale

**MSI= Maintaining Situational Interest; TSI=Triggering Situational Interest**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think the field of biology is interesting. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I learn a lot about meiosis with the mule case study. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I think the field of biology is an important discipline. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I think this class is interesting. (TSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Biology fascinates me. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I think what we are studying in this biology course is useful for me to know. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>The case studies in this class are very interesting. (TSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I enjoy the working through the mule case study. (TSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I’m excited about biology. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I think what we are learning in this course is important. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I find the content of this course personally meaningful. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>This class has been a waste of my time. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>The case studies in this class seem to drag on forever. (TSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>To be honest, I just don’t find biology interesting. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I am enjoying this biology class very much. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I don’t like the case studies very much. (TSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>I see how I can apply what we are learning in this biology course to real life. (MSI)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
</tbody>
</table>
Question 1

One of the characteristics that differentiates all haploid cells from all diploid cells is that

a) haploid cells have half as many chromosomes than diploid cells.

b) haploid cells have one full set of chromosomes while diploid cells have two.

c) haploid cells’ chromosomes have a different structure/shape from diploid cells’ chromosomes.

d) haploid cells have half the amount of DNA as diploid cells.

SELECT THE SINGLE BEST ANSWER
If we pretend that chromosomes remain condensed throughout the cell cycle, what notation best describes the cell pictured below?

a) n=2 (haploid with two chromosomes)
b) n=3 (haploid with three chromosomes)
c) 2n=6 (diploid with six chromosomes)
d) 3n=6 (triploid with six chromosomes)
Question 4

SELECT ALL THE ANSWERS THAT APPLY

One or more of the cells represented below are haploid. Which one is it/which ones are they?

a)  
b)  
c)  
d)
Question 5

SELECT ALL THE ANSWERS THAT APPLY

One or more of the cells represented below are diploid. Which one is it/which ones are they?

a)  

b)  

c)  

d)  

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Question 7

SELECT ALL THE ANSWERS THAT APPLY

Sometimes chromosomes are represented like X’s or like in the picture on the right. This picture represents a

a) chromosome composed of two sister chromatids.  
b) chromosome that has undergone DNA replication.  
c) chromosome in its diploid state.  
d) pair of homologous chromosomes.
Question 11

SELECT ALL THE ANSWERS THAT APPLY

Which of the cells represented below contain a total of eight chromosomes?

a)  b)  c)  d)
Question 12

SELECT THE SINGLE BEST ANSWER
What is the total number of chromosomes in the cell represented below?

a) 2.
b) 3.
c) 6.
d) 12.
Question 13

SELECT THE SINGLE BEST ANSWER

The amount of DNA in a woman's skin cell prior to DNA replication is the same as the amount of DNA in one of her

a) germ cells at metaphase of meiosis I.

a) germ cells at prophase of meiosis I.

a) germ cells that have completed meiosis I, but have not yet started meiosis II.

a) mature gametes (germ cells that have completed meiosis II).
**Question 14**

**SELECT ALL THE ANSWERS THAT APPLY**

Which of the following events occur during prophase of meiosis I?

a) Crossing over of homologous chromosomes.

a) Lining up of homologous chromosomes in the centre of the cell.

a) Pairing of homologous chromosomes.

a) Replication of most of the chromosomal DNA (formation of sister chromatids).
Question 15

SELECT THE SINGLE BEST ANSWER

The diagram below most likely represents the chromosomes of a cell at anaphase of:

a) An impossible situation
a) Meiosis I
a) Meiosis II
a) Mitosis
Question 16

SELECT THE SINGLE BEST ANSWER

The diagram below most likely represents the chromosomes of a cell at metaphase of:

a) Meiosis I

a) Meiosis II

a) Mitosis

a) Meiosis II or mitosis (impossible to tell which one)
Question 17

SELECT ALL THE ANSWERS THAT APPLY

Several cells like the one represented on the right undergo a normal meiosis I and meiosis II, so that each cell produces four daughter cells. One or more of these daughter cells are shown below. Which one(s) could they/could it be?

a)  

b)  

c)  

d)  

_________________________
**Think-a-Loud Procedure**

Individual students were asked to participate in a think out loud review of the case study 2 weeks after the case study was used as a normal part of the course.

The case study was loaded onto a tablet (iPad) using an app (Explain Everything) that can record audio and drawing while students revisit the case study.

The researcher will prompt students such as:

- At this point in the case study, were you interested in solving the problem? Why?
- Did you already know the answer to this part? How were you able to progress at this point in the case study?
- What did you already know about (insert topic/concept) at this point in the case study?
  - Follow-up Question: Since you did not know about (insert topic/concept) how did you stay motivated to keep working with the case study? Were you motivated? What actions did you take to continue working?
- Do you think you learned biology (ie meiosis, cell division, karyotypes) during the case study? How do you know?

Example prompts for conceptual understanding:

If you were at a party and someone said “mules are sterile” what would you say?
- or -

How would you explain Molly’s miraculous birth to friends? How did it happen?
Beliefs About Case Studies Scale-Mule Case Study

The purpose of this survey is to measure how you feel about learning with the "Who's Your Daddy?" mule case study. The data collected from this survey will help researchers understand how students learn from case studies in biology courses. Therefore, it is important for you to answer honestly and that you complete the entire survey.

This is not a test! Your answers will not be used as part of your grade for the course. We ask you to identify yourself only to match you with your other survey data from the study, but your name and identifying information will be removed once the data is collected. Please enter your last name, first intital:___________________________
For each item indicate how strongly agree or disagree with the statement:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>The story helped me remember the scientific content.</td>
<td></td>
</tr>
<tr>
<td>The story kept me interested in the scientific topics.</td>
<td></td>
</tr>
<tr>
<td>The story was not necessary for my learning the scientific topic.</td>
<td></td>
</tr>
<tr>
<td>The story was only for entertainment purposes.</td>
<td></td>
</tr>
<tr>
<td>During the case study, I liked that the professor had us do a lot of the talking.</td>
<td></td>
</tr>
<tr>
<td>I liked the story.</td>
<td></td>
</tr>
<tr>
<td>The story made me want to learn more about biology.</td>
<td></td>
</tr>
<tr>
<td>During the case study, I liked working in groups.</td>
<td></td>
</tr>
<tr>
<td>The story helped me connect the science topics to the real world.</td>
<td></td>
</tr>
<tr>
<td>During the case study, I liked having class discussions with my peers.</td>
<td></td>
</tr>
<tr>
<td>The story was boring.</td>
<td></td>
</tr>
<tr>
<td>I would rather have worked alone on the case study problem.</td>
<td></td>
</tr>
<tr>
<td>I liked having questions to answer during the case study.</td>
<td></td>
</tr>
<tr>
<td>I liked having a problem to solve during the case study (i.e. Who was the daddy?).</td>
<td></td>
</tr>
<tr>
<td>The class discussions distracted me from learning the scientific concepts.</td>
<td></td>
</tr>
<tr>
<td>I would prefer that the professor did all of the talking during class.</td>
<td></td>
</tr>
<tr>
<td>I didn't trust what my peers discussed in class (the answers they came up with).</td>
<td></td>
</tr>
<tr>
<td>I knew about meiosis before the case study.</td>
<td></td>
</tr>
<tr>
<td>I knew about mules or horses or donkeys prior to the case study.</td>
<td></td>
</tr>
<tr>
<td>I am interested in veterinary medicine.</td>
<td></td>
</tr>
<tr>
<td>I was able to relate to the story.</td>
<td></td>
</tr>
<tr>
<td>The types of characters in the story were familiar (animals, farmers, veterinarians) to me.</td>
<td></td>
</tr>
<tr>
<td>The types of concepts in the case study were familiar to me (cell division, karyotypes, homology).</td>
<td></td>
</tr>
<tr>
<td>I learned a lot of biology through the case study.</td>
<td></td>
</tr>
<tr>
<td>Having a story to follow helped me learn about meiosis.</td>
<td></td>
</tr>
<tr>
<td>I think case studies are a good way to learn.</td>
<td></td>
</tr>
<tr>
<td>The case study helped me connect biology to the real world.</td>
<td></td>
</tr>
<tr>
<td>Having a story to follow helped me stay interested during class.</td>
<td></td>
</tr>
</tbody>
</table>
What was your favorite part of the case study?

What was your least favorite part of the case study?
# C. BACS CONSTRUCT VALIDITY AND RELIABILITY

<table>
<thead>
<tr>
<th>Role of the Narrative</th>
<th>Pedagogical Moves</th>
<th>Prior Knowledge</th>
<th>Perception of Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>The narrative plays a role in the learning process.</td>
<td>The structure of the pedagogy helps students stay interested in learning.</td>
<td>Students bring some knowledge or experience to the case study setting and then situate new knowledge.</td>
</tr>
<tr>
<td><strong>Construct</strong></td>
<td>Believes the story helps to make connections between the content and the real world.</td>
<td>Believes aspects of the pedagogy (group work, discussion) helped stay interested in learning the scientific concepts.</td>
<td>Uses previous knowledge about the topic (content) and the story (contextual) during the case study.</td>
</tr>
<tr>
<td><strong>Higher Beliefs</strong></td>
<td>Believes the narrative gives context to the content.</td>
<td>Believes the group work, discussions, and the instructor role helped to stay interested in learning.</td>
<td>Believes the cases study helps them connect science concepts to real world applications.</td>
</tr>
<tr>
<td><strong>Likes the stories, but does not believe they are part of the learning process.</strong></td>
<td>Values the group work, discussions, and the instructor role, but prefers a clear answer from teacher.</td>
<td>Uses some prior knowledge: may use contextual but not content, etc.</td>
<td><strong>Believe they learn some scientific content through the case studies. Believe some content is sacrificed during the case studies.</strong></td>
</tr>
<tr>
<td><strong>Lower Beliefs</strong></td>
<td>Believes the narrative is distracting. Does not connect the stories to their learning. Does not like story.</td>
<td>Does not like the group work. Prefers teacher does all the talking.</td>
<td>Does not possess prior knowledge(s) relevant to the case study.</td>
</tr>
</tbody>
</table>
Items removed from BACS scale to improve reliability.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cronbach’s Alpha if removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>The story was not necessary for my learning the scientific topic.</td>
<td>.75</td>
</tr>
<tr>
<td>The story was only for entertainment purposes.</td>
<td>.77</td>
</tr>
<tr>
<td>I liked having questions to answer during the case study.</td>
<td>.73</td>
</tr>
<tr>
<td>I would prefer that the professor did all of the talking during class.</td>
<td>.74</td>
</tr>
<tr>
<td>I am interested in veterinary medicine.</td>
<td>.73</td>
</tr>
<tr>
<td>The types of characters in the story were familiar (animals, farmers, veterinarians) to me.</td>
<td>.74</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total # Items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 (original)</td>
<td>.72</td>
</tr>
<tr>
<td>22 (after removal)</td>
<td>.85</td>
</tr>
</tbody>
</table>
# D. CODES AND DEFINITIONS

<table>
<thead>
<tr>
<th>THEME</th>
<th>CODE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITUATIONAL INTEREST</td>
<td>Triggers Situational Interest</td>
<td>The story, characters, and dilemma stimulate learning processes such as paying attention or wanting to know more.</td>
</tr>
<tr>
<td></td>
<td>Maintains Situational Interest</td>
<td>Students describe staying engaged (paying attention, participating, persisting) with the learning due to the case study.</td>
</tr>
<tr>
<td>ROLE OF THE NARRATIVE</td>
<td>Real World Connection</td>
<td>Student connects biology to the real world via narrative.</td>
</tr>
<tr>
<td></td>
<td>Understanding Biology</td>
<td>Student attributes understanding biology concepts to the elements from the narrative.</td>
</tr>
<tr>
<td>PEDAGOGICAL FEATURES</td>
<td>Professor as Facilitator</td>
<td>Students recognize that the instructor role is different from other experiences they have had. Students describe generating knowledge themselves or within groups rather than it coming solely from the instructor.</td>
</tr>
<tr>
<td></td>
<td>Group Work</td>
<td>Students attribute group work as part of the learning process during the case study.</td>
</tr>
<tr>
<td></td>
<td>Participatory Environment</td>
<td>Students recognize the case study environment created a space for discourse and participation.</td>
</tr>
</tbody>
</table>
E. MEIOSIS CASE STUDY

See supplemental materials


science classroom: Putting learning by design(tm) into practice Journal of the Learning Sciences, 12(4), 495-547.


