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HOW DO STUDENTS EXPERIENCE A MULTIMEDIA CASE-
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THE INFLUENCE OF ALTERNATIVE PEDAGOGICAL METHODS IN POSTSECONDARY BIOLOGY EDUCATION: HOW DO STUDENTS EXPERIENCE A MULTIMEDIA CASE-STUDY ENVIRONMENT?

By

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ABSTRACT

THE INFLUENCE OF ALTERNATIVE PEDAGOGICAL METHODS IN POSTSECONDARY BIOLOGY EDUCATION: HOW DO STUDENTS EXPERIENCE A MULTIMEDIA CASE-STUDY ENVIRONMENT?

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Bjørn Hugo Karl Wolter

The purpose of this study was to better understand how an online, multimedia case study method influenced students' motivation, performance, and perceptions of science in collegiate level biology classes. It utilized a mix-methods design including data from pre- and post-test, student surveys, and focus group interviews to answer one primary question, did participation in the affect student performance? Two sub-questions were: (a) did participation affect persistence? and (b) did students believe it to be a good learning experience?

One hundred and eight students in 5 classes from 4 campuses in the United States and Puerto Rico participated in this study during spring semester 2009. After receiving instruction on HIV, students took a 6 questions pre-test to measure their initial knowledge of both HIV and lab procedures. Participants then engaged in the Case It! learning environment, where they watched case-studies on HIV, used virtual lab tools, created an online poster of their findings, and role-played as both family members and physicians about their case. A post-test identical to the pre-test was given to students upon completion. Both were then scored using rubrics and analyzed via paired *t*-Tests and ANOVA. The researcher visited all 4 study sites to conduct both the focus group interviews

and student surveys. Student surveys were quantified and descriptive statistic generated. Focus group interviews were video recorded, transcribed, and inductively and deductively coded.

Student knowledge increased because of participation, and the majority of students said they found the Case It! project to be both a good learning experience (95%) and one that would help with future classes or careers (87%). Based on student interviews, the Case It! project did have a beneficial impact on students' intentions to persist as science majors. Many students noted that the learning environment created an overall context in which they could apply knowledge from multiple classes that allowed students to fit all the pieces of their previous academic instruction together into a single, comprehensive picture—and to place themselves within that picture. Students enjoyed the autonomy and personal connections that using case studies and multimedia content offered, and found the material more engaging and relevant. By involving students in real-world situations, Case It! demonstrated the application and effect of theoretical knowledge and stimulated students' curiosity. Case It! appears to be a learning environment that motivates students by making material relevant and personal, thus creating enduring links between students and content which can result in better performance and higher retention rates. It is an effective pedagogical tool that, unlike many other such tools, is *not instructor dependent*, and is adaptable to fit various learner types, settings, and levels.

DEDICATION

This dissertation is dedicated to my family:

to my wife, Stefanie,

whose support, love, and encouragement

kept me at it through the good, the bad, and the utterly neurotic times;

to my daughters, Solveig and Aylin,

who motivated me to better myself to make a better life for them;

and to my mother, Mary,

proofreader and babysitter extraordinaire.

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All graduate students and faculty members before me who developed the assessment tools and rubrics I modified for use in my study, including Hosun Kang, Aroutis Foster, Viola Manokore, Mark Bergland, and Mary Lundeberg.

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CHAPTER 1: Introduction

"Why do we have to know this?" and "How does this apply to the 'real-world'?" are questions educators in Science, Technology, Engineering, and Mathematics (STEM) fields often hear from students. There is a long tradition of lecturing in the sciences, with emphasis placed on memorization and learning material by rote (e.g. Aikenhead, 2006; Seymour, 1995); however, previous research has shown that such methods result in poor student recall and comprehension (e.g. Dale, 1969; Lord, 2007; McDonald & Dominguez, 2005). Furthermore, students often find lectures difficult to relate to, disengaging, and boring (), producing ambivalent or negative opinions of science and a disinclination to pursue degrees and careers in the STEM fields (Astin & Astin, 1993; Seymour & Hewitt, 1997; Tobias, 1990).

Poor pedagogy in STEM courses and programs is affecting student persistence in major. Seymour and Hewitt (1997, pp. 32-35) identify no less than 23 independent factors that affect student retention in STEM fields, the most common of which are poor teaching by faculty, the overwhelming pace and workload of STEM programs, a lack or loss of interest in science, and the belief that other, non-STEM majors are more interesting or present better educational and career opportunities. These findings have subsequently been validated by a number of other researchers (e.g. Aikenhead, 2006; Callahan, Hertberg-Davis, Hockett, & Reed, 2008; Kardash & Wallace, 2001; Kaya, Kilic, & Akdeniz, 2004; National Science Foundation, 1998).

Studies of pedagogy and persistence

One of the largest single factors influencing student retention in STEM fields is teaching (Kardash & Wallace, 2001; Koballa & Glynn, 2007; Osborne & Collins, 2000; Seymour, 2002; Seymour & Hewitt, 1997; Strenta, Elliot, Adair, Matier, & Scott, 1994). In their seminal work, Seymour and Hewitt (1997, p. 33) identify "poor teaching by S.M.E. faculty" as the single most important concern amongst those students who left science and engineering programs (see Table 1). Both Tobias (1990) and Kardash and Wallace (2001) found that students thought the biggest barrier to learning was not the content or difficulty of courses, but rather the pedagogical methods used to convey that knowledge. Instructional method in STEM fields has been largely predicated on a transmission model that, "places personal student issues second to efficient course delivery" (Boldt, 2005, p. 63). Although lectures enjoy a long history of use in most fields of academia, it has become evident that some students do not feel they learn efficiently from them, nor do they particularly enjoy them. Student complaints about lectures include the focus on "getting through" a set amount of material, a lack of connection between theory and application, emphasis on rote memorization, and a lack of interaction between students and faculty (e.g. Kardash & Wallace, 2001; Prince, 2004; Yadav, et al., 2007).

Table 1.

*Factors that cause students to leave STEM programs and concerns of STEM students**

Issue	Causes students to leave STEM programs	Concerning to students who leave STEM programs	Concerning to students who DO NOT leave STEM programs	Concerning to ALL students in STEM programs
Turned off science	43%	60%		49%
Non-STEM majors more attractive	40%			
Poor teaching	36%	90%	74%	83%
Curriculum overload	35%		41%	
Inappropriate reasons for initially choosing STEM program		82%	40%	63%
Poor advising		75%	52%	65%

*Adapted from Seymour & Hewitt (1997, p. 33)

Another major factor limiting student retention in STEM programs has been a lack of engagement in class. Although the use of active learning pedagogies has increased among many STEM programs, many students still feel "turned off" by dry content or delivery (see Table 1; Acker, Hughes, & Fendley Jr., 2002; Astin & Astin, 1993; Seymour, 2002; Seymour & Hewitt, 1997). Several presenters at a recent meeting of the Board on Science Education of the National Academies noted both the need for, and the promise of, active learning in undergraduate STEM education (Dancy & Henderson, 2008; Froyd, 2008; Gregerman, 2008). Felder, Felder, and Dietz (1998) found that students in active and cooperative learning environments in a series of introductory chemical engineering courses had a 17% higher retention rate. Two promising practices that utilize active engagement are undergraduate research programs, which can significantly improve student retention (Gregerman, 2008), and case-based instruction (Lundeberg, 2008; Wolter, Kang, Lundeberg, & Herreid, 2009; Wolter, Lundeberg, & Bergland, 2009). It is hypothesized that case-based instruction involving majors in research might be especially effective in increasing retention.

Student perception of how science affects them or impacts their lives has been a growing problem related to retention in STEM fields (Bovina & Dragul'skaia, 2008; Kardash & Wallace, 2001; Kaya, et al., 2004; Seymour, 1995; Tobias, 1992). Students in STEM programs frequently complain that they feel disengaged from the material. Cited causes of this disenfranchisement include instructional style, an emphasis on rote memorization, or the inability to relate the material studied to their own personal lives (Kardash & Wallace, 2001; McConnell, Steer, Owens, & Knight, 2005). Research has shown that students are more interested in topics that have a direct connection to their own lives, such as sexuality, drug use, or diseases (Aikenhead, 1992; Foster, Wolter, Lundeberg, & Kang, 2008; Stoker & Thompson, 1969; Wolter, Lundeberg, & Bergland, 2009). Other factors related to relevancy that affect persistence are the lack of perceived future benefits, beliefs that non-STEM majors are more interesting or rewarding (Seymour & Hewitt, 1997), dislike for the exclusive culture of science (Aikenhead, 2002, 2006), an inability to perceive the future application of current instruction (Kardash & Wallace, 2001; Wolter, Lundeberg, et al., 2009), and an overall lack of understanding of what it means to be a scientist (Seymour & Hewitt, 1997; Tobias, 1990, 1992).

Just as attracting students into STEM majors has been an issue, so too has been keeping students in the field. Astin and Astin (1993) note that most programs typically experience up to 40% attrition rates. Current students leave STEM programs for many of the same reasons they avoid them initially, but also cite poor teaching, an overwhelming pace and workload, and a chasm between theory and application of knowledge as factors that influence their decisions to leave (Kardash & Wallace, 2001; Seymour & Hewitt, 1997; Tobias, 1990). Many students identify a disconnect between their lives and the science they learn in the classroom.

Schreiner and Sjøberg (2004) argue that it is important to know more regarding what students think *about* science and technology to improve the curriculum. The Relevance of Science Education (ROSE) project addresses issues of declining enrollments in science majors by asking students their perceptions of science and technology (Matthews, 2007), and emphasizes finding relevance between school topics and students' lives (Sjøberg & Schreiner, 2005). The ROSE questionnaire has been administered in more than 37 countries, and indicates students are most interested in health, sexuality, genetics, the origin of life, space, the universe, and natural disasters (Matthews, 2007). However, *how* a topic is taught also matters, not just the nature of the topic. The method in which material is presented to students has the potential to affect student motivation, and by extension both performance and persistence (e.g. Allen, 1999; Cornell & Martin, 1997; Malone, 1981a, 1981b; Theall & Franklin, 1999).

As mentioned above, many researchers believe that both PBL and CBI can influence student persistence in STEM programs. A growing body of literature emphasizes the relevance of multimedia, case-based science learning to students, especially in undergraduate science courses (Herreid, 2001, 2005a, 2005b; Lundeberg, et al., 2002; T. M. Smith & Emmeluth, 2002; Sokolove, Marbach-Ad, & Fusco, 2003). Prior research has indicated that students become more engaged with, and interested in, science when it is made culturally relevant to their lives (Aikenhead, 2002, 2006; Wolter, Lundeberg, et al., 2009).

Studies from the field of engineering. Student persistence in STEM fields has been highly correlated to secondary schooling preparation in the sciences and GPA (Bonous-Hammarth, 2000; Cole & Espinoza, 2008; Huang, Taddese, & Walter, 2000); however, there is little literature on how exactly alternative pedagogical techniques impact retention in the sciences. The field of engineering appears to be far more proactive in this research than other STEM fields. Nationally, engineering programs experience high rates of attrition. In response, researchers in engineering education have dedicated a significant amount of time to the issue, finding that fewer students leave programs that emphasize "real-world" application and connections with content (Fortenberry, Sullivan, Jordan, & Knight, 2007; Froyd & Ohland, 2005), and that a student services approach featuring peer-mentoring and counseling appears to positively influence student retention rates (Sleeman & Sorby, 2007).

Felder and his associates (Felder, 1995; Felder, et al., 1998; Felder, Felder, Mauney, Hamrin Jr., & Dietz, 1995) conducted an extensive longitudinal study of student instruction, retention, and performance in one engineering program from 1990 to 1993. One of their findings was that traditional, transmission model introductory courses that emphasize the roles of competition and individual, rather than group, work discourage women and minorities from persisting in STEM programs (Felder, et al., 1995), and that incorporating coursework that stresses and rewards cooperative learning has the potential to reduce the attrition of women in engineering programs (Felder, et al., 1995).

Felder's massive study also concluded that instructional pedagogy that incorporates cooperative, group-based work was not only more effective in helping students master content (Felder, 1995), but may also play a part in programmatic completion since students were more confident in their knowledge, and had better attitudes toward instruction (Felder, et al., 1998). Other studies have demonstrated that cooperative learning communities show promise in increasing student completion rates and retention rates (Tsang & Halderson, 2008). Early involvement with research and information about the nature of the discipline have also been shown to have positive effects on student perceptions and persistence (e.g. Fairweather, 2008; Gregerman, 2008).

Potential solutions. Even though previous studies of STEM pedagogy are limited, they do provide useful insight into what actions might beneficially influence student success in STEM programs. Major factors affecting student persistence include: (a) an overall lack of motivation due to poor instruction; (b) feeling dissociated from the social structure of the sciences; (c) bad advising; (d) waning interest in the sciences due to impersonal pedagogies and disinterested faculty; (e) level of preparation; and (f) awareness of discipline (Seymour & Hewitt, 1997; see Table 1). Previous studies have highlighted the importance of improving instruction in STEM fields (e.g. Herreid, 2006; Kardash & Wallace, 2001; Seymour, 2002; Seymour & Hewitt, 1997; Tobias, 1992), which may be accomplished in many ways.

Many researchers (e.g. Burrowes, 2003; Felder, et al., 1998; Kumar & Sherwood, 2007; Lundeberg, et al., 2002; Prince & Felder, 2007; Seymour, 2002; Wolter, Kang, Lundeberg, & Herreid, 2009) advocate a shift from instructor-centered pedagogies such as lectures toward student-centered, active engagement instruction like problem-based learning (PBL) and case-based instruction (CBI). In PBL students work in groups to collectively solve poorly structured, open-ended problems (Savery, 2006). CBI environments are similar, but are more structured, using engaging narratives to introduce students to an issue (Herreid, 1994; Lundeberg, Levin, & Harrington, 1999). Recent research studies in CBI have investigated the effect of incorporating technologies like personal response systems (Wolter, Kang, Lundeberg, & Herreid, 2009; Wolter, Kang, Lundeberg, Herreid, & Zhang, 2009), and the importance of personal relevance (Wolter, Lundeberg, et al., 2009). Other researchers (Gregerman, 2008; Hunter, Laursen, & Seymour, 2007; Taraban & Blanton, 2008) have identified the incorporation of undergraduate research into programs as another technique with the potential to address the underlying causes of student attrition. All of these practices have the potential to speak to issues of engagement, relevancy, and motivation in STEM instruction.

Deficiencies of previous studies

A wealth of articles exist identifying the need for improved pedagogy in STEM fields; however, many of these simply identify the lack of even adequate instruction as an issue without identifying potential strategies for improvement (e.g. Astin & Astin, 1993; Augustine, et al., 2006; Seymour, 2002; Seymour & Hewitt, 1997; Tobias, 1990, 1992). Other studies identify broad ideas to address the issue, but lack specifics about tools or implementation (e.g. Aikenhead, 2007; Bailek & Botstain, 2004; Bell, 2004; Burrowes, 2003; Irwin, 1995; Kumar & Sherwood, 2007). This is not to say that experimental studies of pedagogy in STEM programs do not exist—they do—but most focus on reaching specific disadvantaged groups (e.g. Hurtado, et al., 2008; Hurtado, et al., 2007; Kang, Wolter, Lundeberg, & Herreid, 2009; O. Lee & Luykx, 2007; National Science Foundation, 2003), or investigating barriers in adopting alternative pedagogies (e.g. Moriarty, 2007; Seymour, 1995; Walczyk, Ramsey, & Zha, 2007). There is a limited body of literature on effective pedagogical techniques in STEM (e.g. Bergland, et al., 2006; Lundeberg, et al., 2002; Wolter, Kang, Lundeberg, & Herreid, 2009; Wolter, Kang, Lundeberg, Herreid, et al., 2009; Wolter, Lundeberg, et al., 2009), to which this study adds.

Importance of the study

Science education researchers have known for over 25 years that poor teaching is a major issue deterring undergraduates from majoring in STEM fields; however, there is lack of empirical information on effective pedagogical tools in the existing body of literature. Even though we know what does not work for students, because we lack information on effective strategies, and because of the conservative nature of instruction in most STEM fields, teaching still tends to adhere to the traditional lecture/transmission model of education that emphasizes rote memorization, is disengaging, and fails to illustrate the validity of content to students' lives.

Purpose

This study attempted to contribute to the existing knowledge base on effective STEM pedagogy by exploring the influence of an alternative, online instructional tool in undergraduate, majors-level biology classrooms across diverse sites in the United States and Puerto Rico. It examines the effects of the learning environment on student motivation, performance, and perceptions of what makes for good instruction in biology. In this study, pre- and post-test assessments were used to measure the relationship between instructional method and student performance. A student survey and focus group interviews evaluated student perceptions of their experience and intentions to persist in program. Case studies were developed in parallel at each of the five study sites, incorporating student performance statistics, focus group interviews, and student opinion surveys.

CHAPTER 2: Literature Review

This review will focus on research detailing the current state of postsecondary biology instruction, including the problems it is facing. The growing use of instructional technologies will then been discussed, as well as models of student motivation in collegiate classrooms. Finally, the research questions of this study will be presented.

The current state of postsecondary biology

Many students report the lack of adequate instruction in STEM fields as a major factor affecting their persistence in programs. One anonymous reviewer of Seymour and Hewitt (1997) stated, "[As a science major] plan your educational strategy to avoid being 'weeded out' by SME faculty who don't want to admit that you exist until you have put up with two solid years of cheerful neglect and brutal abuse" (Anonymous 1999). Although lectures are a traditional method of instruction in most sciences, many of today's students are bored and disenfranchised with them. Students of all backgrounds frequently cite the stereotypical "talking head" lecture used for the past century in science education as a major detraction (Kardash & Wallace, 2001; Lord, 2008; Moriarty, 2007; Wolter, Lundeberg, et al., 2009). Wolter, Lundeberg, and Bergland (2009) found that students in introductory biology thought classroom science was boring or irrelevant; however, when material was placed in a relevant context to their own lives, students become both more engaged and interested in science.

Content vs. pedagogy. In the 20 years since Boyer (Boyer, 1990) wrote about the need of the American professoriate to reconsider its priorities, most institutions will say that they value effective teaching—especially in the STEM fields—but the realities are somewhat different. No American college or university in its right mind will say that it does not value teaching; however, faculty reward structures tell a different tale. The fact remains that most faculty tenure systems at American universities and colleges are designed to reward research and conversely punish teaching (Fairweather, 2005; Leslie, 2002). This is demonstrated by the fact that at all 4-year institutions, regardless of type, the more time faculty spend on teaching, the lower their average pay (Fairweather, 2005). Fairweather (2008, p. 23) observes that,

> ...Career publications remain the strongest predictor of faculty pay *irrespective of type of institution* (emphasis in original). An economic analysis of the estimated effect of an additional hour spent in the classroom and an additional career publication at the mean shows that it costs money to spend time teaching whereas publishing is invariably rewarded with higher pay.

This institutionalized paradox in values of has carried over to faculty attitudes where it manifests as an argument about whether to teach STEM courses based strictly on content supported by research, or based on effective pedagogy supported by the scholarship of teaching. There is an enduring perception amongst STEM faculty that improving instructional quality comes at the cost of research productivity (Boardman & Bozeman, 2007; Fairweather, 2005; Parker, 2008). Leslie (2002) notes that there exists a contradiction in faculty attitude where teaching ability is valued, but research activity is perceived as the primary force influencing career goals such as tenure and status.

Research activity is frequently grant-driven, and every institution takes their cut of any grant received by their faculty; therefore, the benefits of research for the institution are bi-fold, (a) they receive income indirectly via it, and (b) the publications that result from research increase their prestige. Teaching, however, results in neither of these. Realistically students will continue to attend higher education regardless of whether instructional reforms happen, therefore the is little financial incentive for institutions to reward teaching which is perceived as coming at the cost of research. Although the benefits of pedagogical reform in STEM fields has been established, Fairweather (2008, p. 24) notes that, "…enhancing the value of teaching in STEM fields requires much more than empirical evidence of instructional effectiveness. It requires active intervention by academic leaders at the departmental, college, and institutional level."

STEM faculty vary considerably in attitudes and behaviors towards instruction and students (Fairweather & Paulson, 2008); however, Pascarella and Terenzini (2005) demonstrated that the most effective teaching techniques are not discipline dependent. Those professors who do make the effort to reform the structure of their classes primarily focus on individual classroom-level interventions, such as shifting away from lectures and toward more learner-centered actives (Fairweather, 2008). Despite the preponderance of evidence that changes in pedagogy can positively influence student opinions, performance, and retention in STEM courses (e.g. Eiseman & Fairweather, 1996; Fairweather & Beach, 2002; P. Fisher, Zeligman, & Fairweather, 2005; Wankat, 2002), there has been none of the looked for macro-level change because reform dies out without institutional and faculty support (Fairweather, 2008).

Individual vs. systemic instructional reform. Instruction that integrates active and collaborative learning with engaging contexts results in better student performance irrespective of academic discipline (Fairweather, 2008; Kuh, Kinzie, Buckley, Bridges, & Kayek, 2007; Kuh, Kinzie, Schuh, & Witt, 2005). As noted above, successful pedagogical innovations in STEM education frequently are isolated to developers because reform efforts are widely viewed as voluntary professional development (Fairweather, 2008; Wulff & Austin, 2004).

Strong pedagogy is frequently instructor dependent, rather than applicable across a wide variety of institutions, students, and faculty, resulting in a problem "scaling up" (e.g. Eiseman & Fairweather, 1996; Fairweather, 2008; Kumar & Sherwood, 2007; Yadav, et al., 2007). While classroom instructional reforms have demonstrated site-specific efficacy, they have not led to the expected systemic reforms in student retention and comprehension. Studies such as Fisher, Zeligman, and Fairweather (2005) have shown reformist techniques can be extremely effective in improving student scores and critical thinking, but often fail to have systemic effect because such techniques are instructor specific and they are not integrated into programmatic curriculum.

The faculty who choose to participate in professional development are already demonstrably committed to improving instruction (Gappa, Austin, & Trice, 2007); however, most STEM faculty, are not trying to maximize their teaching efficacy, but rather to teach well enough so they can maximize research time (Massy & Zemsky, 1994). It is arguably with those instructors that even modest gains in STEM pedagogical reform will be made (Fairweather, 2008; Labov, Singer, George, Schweingruber, & Hilton, 2009).

Pace of change. A major problem facing STEM instruction in the 21st century is the ability (or lack thereof) of the curriculum to reflect and incorporate the latest developments from the field. The pace at which the American educational system changes is a long-standing joke, frequently resulting in the question, "What change?" While the educational system might be highly conservative with a great deal of institutional inertia (Duderstadt, 2000; Wallis & Steptoe, 2006), knowledge within disciplines evolves faster every year (e.g. Bush, 2009; Knight, 2007). Many STEM professors still rely heavily on both textbooks and publisher provided instructional material, even though they always lag behind the leading edge of discovery in field because of the publication process (e.g. Yore, 1991). Pedagogical tools that can eliminate this lag time between discovery, implementation, and incorporation into curriculum could significantly impact the quality of instruction in STEM education.

Bioinformatics. Biology and life sciences are undergoing a rapid change in the way that systemic and molecular information is collected and processed

(Emmott & Rison, 2006). Bioinformatics combines techniques from computer science, molecular biology, genetics, statistics, applied mathematics, and systematics to answer questions in biology primarily dealing with large-scale DNA-sequencing, protein structure, and molecular processes (Baldi & Brunak, 2001; Cristianini & Hahn, 2006). Examples of current research projects include the Human Genome Project, synthetic drug design, modeling evolution, and predictions of gene expression (Zvelebil & Baum, 2007). Bioinformatics scientists collect and analyze massive amounts of data about the genetic and molecular components of entire biological systems to increase understanding of biological processes. By using computers to assist in mapping DNA and protein sequences, researchers can deduce links and interactions, and making sense of the relationships between, within, and amongst systems (Baldi & Brunak, 2001; Cristianini & Hahn, 2006; Emmott & Rison, 2006; Zvelebil & Baum, 2007).

Reforms in STEM education.

Case-based instruction. Case-based instruction has been used in higher education since 1927 (Kagen, 1993), primarily in professional education fields, such as law, business, and medicine (Herreid, 2006; Lundeberg, et al., 1999). However, the pedagogy has become increasingly popular as an instructional vehicle across educational fields (Herreid, 1994; Kang & Wolter, 2008; Yadav, et al., 2007). Prince and Felder (2006) incorporate case-based instruction under the umbrella of inductive teaching techniques, and closely associate it with other student-centered and student-directed pedagogies such as

PBL, discovery learning, just-in-time teaching (JiTT), and inquiry-based learning (Savery, 2006).

Case-based instruction is a valuable and valid pedagogy because it allows students to individually develop their own knowledge bases and pathways on a subject such that it is both relevant and important to them (Levin, 1999; Savery, 2006). The use of case studies in science education can result in students making a meaningful connection with the material, improve understanding, and increase engagement (Kumar & Chubin, 2000; Kumar & Sherwood, 2007; Rybarczyk, Baines, McVey, Thompson, & Wilkins, 2007; Yadav, et al., 2007). The complex nature of case studies leads students to assess problems from a myriad of perspectives (Bell, 2004), and those that emphasize the human dimension of an issue or controversy may be able to powerfully demonstrate the relevance of a given topic to students and generate engagement (Bell, 2004; Yadav, et al., 2007). In providing students with real-world problems in a situated learning contexts, case studies motivate students to learn by making the material both relevant and engaging (Bergland, et al., 2006; Prince & Felder, 2006).

A recent national study found that faculty who use case studies believe their students develop both stronger analytical cognitive abilities, and a deeper understanding of the topic (Yadav, et al., 2007). Other research has verified this faculty perception, showing that the use of case-based learning in science education can significantly promote knowledge acquisition, the development of critical thinking skills in students, and student retention (Burrowes, 2003; Dori, Tal, & Tsausu, 2003; Prince & Felder, 2007; Rybarczyk, et al., 2007; Savery, 2006; R. A. Smith & Murphy, 1998). Choi, Lee, and Jung (2008) have developed data that suggests the use of online multimedia case-studies may be especially effective in accessing sensing, sequential, and reflective learners.

Advancement in the sciences can be represented as an ever-narrowing pipeline whose traditional teaching methodologies tend to cause students to dropout because of the emphasis on rote memorization, lack of situated application, and perceptions of poor teaching (Kardash & Wallace, 2001; Seymour & Hewitt, 1997). Kardash and Wallace (2001, p. 199) note in their study of student perceptions of science classes that, "...how information is taught appears to be at least as much of concern as what information is taught." Many researchers believe that case-based instruction has the potential to alleviate these instructional issues by providing real-world situations in which students explore and apply knowledge through discovery and application (Herreid, 2006; Lundeberg, et al., 1999; Lundeberg, et al., 2002; Lundeberg & Yadav, 2006a, 2006b; R. A. Smith & Murphy, 1998; Wolter, Lundeberg, et al., 2009). Because of this, the use of case-based learning across disciplines is projected to increase as more postsecondary institutions embrace "...social constructivist and situated learning pedagogies" (Oblinger & Oblinger, 2005, p. 243) in the 21st century.

Case based instruction has the potential to address many of the issues relating to retention in the STEM fields. It (a) creates active engagement (Herreid, 1994, 2006b; Lundeberg, et al., 1999), (b) motivates students via working on "authentic" tasks and real world problems (Bergland, et al., 2006; Herreid, 1994, 2006b), (c) promotes active learning (Callahan, et al., 2008; Lundeberg, et al., 1999), (d) promotes higher-order thinking skills (Dori, Tal, & Tsausu, 2003; R. A. Smith & Murphy, 1998), (e) helps students set content mastery goals (Rybarczyk, et al., 2007; Savery, 2006), (f) exposes students to ethical and societal problems (Herreid, 1994; Kang & Lundeberg, 2008; Lundeberg, et al., 2002), and (g) causes students to examine problems from multiple perspectives (Herreid, 2006; Wolter, Lundeberg, et al., 2009).

Case-based instruction is not without its difficulties. Yadev et al. (2007, p. 37) identified five major obstacles that faculty encounter when using cases: (a) lack of preparation, (b) how to assess student learning and participation, (c) a lack of relevant cases, (d) student resistance to case-based instruction, and (e) pressure to cover more content. Herreid (2003) provides a narrative of the complete failure of a case-based course due to disorganization and the use of multiple instructors. While the benefits of using case studies in science education have been well documented, challenges such as these may deter those uninitiated to case-based instruction.

The growing use of instructional technology in STEM instruction. Since the advent of the first computers more than 50 years ago, their integration into teaching environments has steadily increased. Computer-assisted instruction (CAI) has become widespread and integral to education from the primary to postsecondary levels (Chambers & Sprecher, 1984; Keller, 2008; Ko &

Rossen, 2010). At the collegiate level, virtually every professor communicates with students via email, utilizes online course management software, teaches in a multimedia-enabled classroom, creates content on their PC, or teaches online. This trend continues to grow as new, "digital native" (Oblinger & Oblinger, 2005) professors integrate technology into the classroom. A recent report by the Microsoft Corporation (Emmott & Rison, 2006) notes that the importance of technology in STEM instruction will only continue to grow in the next decade, require an urgent reevaluation of how programs train future both future practitioners and professors. The authors also assert that technology will have particular significant impacts on biology and chemistry where it can assist in the conceptualization of especially abstract yet vital concepts (Emmott & Rison, 2006). The following are just a few examples of how technology is changing collegiate instruction.

Clickers. Personal Response Systems, or "Clickers," are an instructional technology whose use has surged on campuses across America in the past decade. There are many manufacturers of systems, and the devices themselves range from simplistic 5-button remotes to units that resemble graphing calculators; however, all virtually all use local radio frequency (RF) signals to create a classroom network that links student clickers to a receiver attached to the professor's computer. Clickers provide immediate, real-time feedback to students in even the largest lecture hall, directly influencing student learning (e.g. Guthrie & Carlin, 2004; Mayer, et al., 2009). Although instructors must create most questions ahead of class, they are able to instantly estimate student comprehension. Student interaction and feedback are proven and important facilitators of student learning (Carini, Kuh, & Klein, 2006; Herzog, 2007), and previous studies suggest that students: (a) pay more attention; (b) develop independent, personally intuitive, organization of concepts; and (c) engage in metacognitive self-evaluation when lectures incorporate clicker questions (Duncan, 2005; Mayer, et al., 2009). Clicker use has also been linked to improved motivation (Crouch & Mazur, 2001), which may lead to cognitive persistence (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996), and increased mastery goal setting (Roschelle, Penuel, & Abrahamson, 2004). Duncan (2005) demonstrated the efficacy of using clickers as an active learning strategy to improve both student performance and opinion in large science lecture classrooms.

The successful use of clickers is associated with several educational theories, such as the importance of feedback (Cain, Black, & Rohr, 2009; Yourstone, Kraye, & Albaum, 2008), student motivation (Trees & Jackson, 2007), and generative learning (Mayer, et al., 2009). Previous researchers (e.g. Guthrie & Carlin, 2004) indicated that clickers provide an excellent source of feedback, which may directly influence student learning. By using clickers, professors are able to answer students' questions instantly, and students are more engaged when instruction centers on the discussions of these questions (Duncan, 2005).

Horowitz (1988) reported that by using a student response system, students significantly increased their attentiveness during the class.

A recent 3-year, longitudinal study (Mayer, et al., 2009) focused on the utility of using clickers facilitate faculty questions, student response, and student attention. The authors emphasize that each of these factors is essential to creating engagement, which is in turn vital to student learning, stating

> If students do not feel they are involved in the learning situation, they are less likely to work hard to make sense of the presented material and therefore less likely to perform as well as they could on assessments measuring their learning. (Mayer, et al., 2009, p. 51)

The researchers used 3 experimental groups, a control (no clickers or questions), a no-clicker group (questions and paper-based responses), and a clicker group (questions and clickers). They found that the clickers treatment group scored significantly higher on midterm and final exams combined than either the control or no-clicker group (Mayer, et al., 2009). It is interesting to note that students who receive the same questions as the clicker group, but responded via paper scored significantly lower than the clicker group, indicating that the clicker condition itself was aiding student learning, and not just the question method of instruction. These findings articulate well with the primary thesis of generative learning theory that cognitively engaged students learn more (Mayer & Wittrock, 2006).

While there are advantages to incorporating clickers into large lecture classrooms, Mayer, et al. (2009) point out that there are major challenges facing higher education in implementation and how to integrate these benefits in ways that promote student *learning* and not necessarily just student performance.

Games and computer simulated learning environments. The use of games and simulations has become common amongst those interested in discovery-oriented science education (Kulik, 2002). Previous studies have shown that both can significantly impact a student's ability to construct personal knowledge and meaning, as well as develop collaborative learning skills (e.g. Jackson, 2009; Lai-Chong Law, Kickmeier-Rust, Albert, & Holzinger, 2008; Ryan, Rigby, & Przybylski, 2006; Vogel, et al., 2006). The structure of actions in games may also allow students to develop higher-order skills because they control the activity and must make decisions in response to stimuli, requiring them to strategize and engage in *Judgment-Behavior-Feedback loops* (Garris, Ahlers, & Driskell, 2002).

Video games and simulations are effective instructional tools for multiple reasons. Mayo (2009) notes that games and simulations are effective because they utilize many pedagogical techniques that have been proven effective in other situations. These include such items as the ability to vary the pace of the game to fit the user and the ability to present information in multiple ways so as to access as many learning types as possible (Gee, 2003). Games and simulations also offer scalable delivery of information where complex issues or goals are first presented as small, accomplishable tasks, which are then repeated several times before evolving into more complex scenarios. This method of deliver is also known as “concurrent chaining” (Peck & Detweiler, 2000), and allows students to build confidence in the knowledge and skills necessary to accomplish tasks. Video games give information “situated meaning” (Mayo, 2009) and reinforce key concepts, as well as providing students social interactions associated with content, all of which drives learner motivation, engagement, and achievement (Keller, 2010). By giving students control and autonomy over task and activities within the learning environment, simulations improve learning outcomes (Vogel, et al., 2006), enjoyment, and motivation (Ryan, et al., 2006). Video games are fun, active learning environments where students are instruments of their own learning. Because of this, they are more apt to spend longer periods of time interacting with the material, and hopefully making meaningful connections with it (Jackson, 2009; Keller, 2010; Mayo, 2009). Gaming simulations also describe many of the tenets of Merrill’s (2002) model for successful learning, such as containing an intrinsic motivation to play, having clear rules and goals, providing an attractive learning environment, using an engaging, yet unpredictable storyline, providing immediate feedback, and being interactive, challenging, and competitive (Lai-Chong Law, et al., 2008; Prensky, 2001).

Studies have shown that dynamic, computer-based simulations can enhance student comprehension and retention of complex topics (Trey & Khan, 2008) and significantly improve student performance (Holzinger, Kickmeier-Rust, & Albert, 2008) beyond the capabilities of fixed measures, such as text. They may also increase learning 7-40% over lectures (Mayo, 2009; Vogel, et al., 2006). Most researchers agree that this is because simulations provide students with simplified models of real-world situations that help them integrate a wide array of facts, ideas, and principles from multiple sources (Kulik, 2002; Ryan, et al., 2006; Vogel, et al., 2006). Games also tend to focus on higher-order instructional objectives, requiring students to do more than just memorize facts and actively involving them in the learning process (Kulik, 2002).

The ability to manipulate parameters in simulated environments allows students the ability to experiment with outcomes and actively engage in both self and scientific discovery in a very real and personal manner (Clark, Nelson, Sengupta, & D'Angelo, 2009; Llado & Sanchez, 2009). In addition to developing scientific reasoning and skills, simulations can also develop students' deep-reasoning, analytical abilities, and personal meaning-making in relation to the content (Clark, Nelson, Sengupta, & D'Angelo, 2009). Video games and simulations also offer multiple levels of interaction with material analogous to the multiple levels of interaction students have with material in science classrooms (Jackson, 2009).

Kulik (2002) notes that while games and simulations have the potential be useful instructional tools, simply including them in a curriculum does not guarantee success. Far too often it is predicated on the individual instructor's ability to utilize simulations as a medium (Becker, 2007), rather than on the efficacy of the learning environment. Few examples exist of simulated environments in science that remove the instructor as a variable in the success of the program.

Models of student motivation

Student persistence in any program is arguably a product of motivation to *stay* in that program (Allen, 1999; Theall & Franklin, 1999). If a student is inspired by their class-related, personal, and social experiences in a course of study, they are far more likely to remain in program than students who feel alienated, isolated, ignored, and otherwise de-motivated by their encounters (e.g. Pintrich, 2003; Vallerand, Fortier, & Guay, 1997). *Motivation* is broadly defined as what an individual wants, needs, or desires, while *motives* are those stimuli that cause one to act upon them (Glynn, Aultman, & Owens, 2005; Koballa & Glynn, 2007). Brophy (2004) tell us that, "In the classroom context, the concept of *student motivation* is used to explain the degree to which students invest attention and effort in various pursuits…" (p. 4, emphasis in original).

In general, the many theories of student motivation can be grouped into four categories: (a) physiological; (b) behavioral; (c) cognitive; and (d) emotional (Keller, 2010). Of the four, behavioral and cognitive theories are the most common (e.g Brophy, 2004). The legacy culture of education in the United States from Kindergarten through post-secondary schooling is predicated on a behavioralist perspective of motivation that presupposes people only respond to basic needs. An example of this point of view would be to assume a student's only motivation to perform in class is to attain a passing grade, which is necessary to move on to the next class or to obtain their degree. Thus, behavioral models of student motivation are based on the manipulation of students, whereas cognitive models emphasize engaging and interacting with students (Alberto & Troutman, 1999; Brophy, 2004).

Researchers recognize that student motivation is far more complex than the "carrot-and-stick" model that rewards desired behaviors and punishes unwanted ones. Motivation can be derived from multiple sources, and is not necessarily an intrinsic value but can be a product of expectations, meaningful content, and student-centered activities (Brophy, 2004; Druger, 2000; Maehr & Braskamp, 1986). Just as motivation can be the product of multiple sources, so too can it be view from multiple perspectives. In a summary of research, Renchler (1992) notes that motivation can be viewed as: (a) a personal trait, like a highly competitive student gaining personal validation through being the "best;" (b) a response to specific environmental stimuli, such as the praise or regard of a valued peer or teacher; or (c) a product of student cognition, such as a sense of control or ownership or a self-image the student is motivated to maintain.

The ARCS model of student motivation. Of the many theories of student motivation, few are as well known and have such a preponderance of support as Keller's ARCS model (Keller, 1979, 1983, 1987, 2010). Keller asserts that student motivation in any course is a product of 4 factors: (a) Attention; (b) Relevance; (c) Confidence; and (d) Satisfaction.

Attention. To motivate students, any course or project must gain and keep the students' curiosity. To do this instructors can use perceptual arousal, analogous to sensory stimuli, in which novel, incongruous, or surprising elements are introduced. Inquiry can also keep students' attention by asking them to answer or develop questions, or to solve specific problems. Keller (2010) suggested a third method of gaining attention is through variability, maintaining interest by using different techniques, methods, or sources of information.

Relevance. One of the most important things for any learning environment to do is to demonstrate to students *how* the material being presented does or may affect students *personally*. If students find content to be pertinent or useful to them, they are more likely to be motivated (Wolter, Lundeberg, et al., 2009). Potential benefits and uses should be emphasized and reinforced by using specific examples and analogies that draw links between the students' lives and the material being learned. Assessing individual student ambitions and demonstrating how those goals may be met can also build relevance (Keller, 1999, 2010).

Confidence. Building confidence and perceptions of self-efficacy reinforces motivation. Students need to believe that they can succeed at the tasks they are given; however, they also need to be challenged. Tasks that are too easy make students feel they are wasting their time and detract from overall motivation to learn. Keller and Suzuki (1988) note that there are three important motivational dimensions to student confidence. First is *perceived competence* in which students are motivated in situations where they believe they have the skills needed to succeed; however, learning usually involves utilizing new skills and knowledge bases where pupils feel less confident. Therefore, to optimize motivation in these scenarios, students need controlled environments where mistakes may be made without embarrassment. Second is *perceived control,* which is exercised when students feel their actions and choices directly affect the outcome of situations, and they therefore feel more in control. Control breeds confidence, which in turn breeds motivation and persistence. Third is an *expectancy for success,* which has also been called "Self-fulfilling prophecy" (Jones, 1977; Schunk & Pajares, 2009) where because students believe they can accomplish a task, they exert more effort and perform better. This is an important observation because actual probabilities of success do not necessarily factor into student psychological expectations. In the STEM fields it is not uncommon for students to suppose material will be simply too hard to comprehend, resulting in failure even where objective odds would suggest success (Keller & Suzuki, 1988; Wolter, Lundeberg, et al., 2009).

Strategies to increase confidence may include allowing students personal control so they are the facilitators of their own accomplishments, providing multiple opportunities for achievement where students can gain validation, and providing detailed requirements that allow students to gauge their likelihood of success. It should be noted however that while confidence can beneficially affect both performance and motivation, over-confidence may have the opposite effect and in fact de-motivate students (Hackett & Betz, 1989; Nietfeld, Cao, & Osborne, 2005).

Satisfaction. Learners need to gain some feeling of reward or satisfaction with their experiences to remain motivated. Keller and Suzuki (1988) note that, "if the outcomes of learners' efforts are consistent with their expectations, and if they feel good about the outcomes, then they are likely to remain motivated" (p. 405). Satisfaction may manifest as a sense of accomplishment—that the tasks performed were important and worthwhile, or as a feeling of success—that they are capable of performing. Additionally, students who feel a sense of pride in their accomplishments are more likely to both retain information and remain motivated. Factors that may influence student satisfaction may include: (a) reinforcement and feedback, which can sustain motivation; (b) predictable, intrinsic rewards, which can result in consistent behavior; and (c) cognitive evaluation, which includes reflective praise for accomplishments from both peers and instructors (Keller, 2008, 2010; Keller & Suzuki, 1988; Shellnut, Knowltan, & Savage, 1999; Visser & Keller, 1990).

Keller's ARCS model of student motivation has been extensively researched (Deimann & Keller, 2006; Means, Jonassen, & Dwyer, 1997; Small & Gluck, 1994; Visser & Keller, 1990), and its validity well established. Recent research has also established its applicability to computer-based, online, and distance learning environments (Astleitner & Wiesner, 2004; Keller, 1999, 2008; Keller & Suzuki, 2004; Song & Keller, 2001). Other research by Cornell and

Martin (1997) has shown that in online and distance courses, student motivation, persistence, and performance can be influenced by instructional design.

The Expectancy x Value model of student motivation. This is an inclusive model that places motivation within a social context where motivation is the product of students' expectations of success and degree to which they value such success (Brophy, 2004; Feather, 1982; Wigfield & Eccles, 2000). In other words, if students either do not believe they can succeed, or see no reason to, they are not motivated. Brophy (2004) draws a distinct difference between *learning*, typically defined as comprehension, processing, or mastery, and *performance*, the simple demonstration of knowledge. He theorizes that student motivation to learn is related to students' intentional learning processes, not their performance (Brophy, 2004). Based on this model, to be motivated, students must have expectations for success (e.g. clear goals, a belief in success), and intrinsic factors, those which access personal values or interests. Many of these intrinsic factors overlap with factors identified in the ARCS model as creating motivation (Keller, 1979, 1983, 2010).

Principle factors in motivating students to learn. Merrill (Merrill, 2002, p. 43) identifies five core principles of learning and motivation common to all theories, stating that learning is promoted when:

1. Learners are engaged in solving real-world problems.
2. Existing knowledge is activated as a foundation for new knowledge.
3. New knowledge is demonstrated to the learner.

4. New knowledge is applied by the learner.
5. New knowledge is integrated into the learner's world.

Keller (2008) takes these five principles a step further in applying them to digital environments, stating that motivation to learn is promoted when:

1. Curiosity is aroused by gaps in current knowledge.
2. Material learned is perceived to be relevant and meaningful to the learner.
3. Learners believe they can succeed in mastering the task.
4. Learners anticipate and experience satisfying outcomes to a learning task.
5. Learners employ volitional strategies to protect their intentions.

Motivation and persistence. Student motivation to learn is a cognitive function of trying to contextualize and understand material that utilizes specific mental pathways (Brophy, 2004). These pathways are activated by certain aspects within a learning environment, such as those illustrated by the ARCS model (Keller, 1983) that grab the learners attention, establish the relevancy of the material, build learner confidence, and develop a sense of satisfaction. Previous research has linked the use of PBL and CBI learning environments to improved student motivation (e.g. Ertmer, Newby, & MacDougall, 1996; Hmelo-Silver, 2004; Lee, 2007; Richardson, 1993), because these tools have the potential to create cognitive dissonance and curiosity. Numerous researchers of college student retention have noted that persistence is the product of several social and academic sub-categories including motivation, social integration, and self-direction (e.g. Baird, 2000; Braxton & Lien, 2000; Stage & Hossler, 2000; Tinto, 1993, 2000). Other researchers have demonstrated that motivation can beneficially impact both program persistence and academic performance (e.g. Allen, 1999; Glynn, et al., 2005; Koballa & Glynn, 2007; Renchler, 1992; Theall & Franklin, 1999; Vollmeyer & Rheinberg, 2000) by engaging students in such a way that individual and academic goals align. It is expected that the learning environment being investigated in this study, Case It!, will have positive effects on persistence in program, performance, and student opinion.

Research questions

Declining numbers of undergraduate majors and graduate students in STEM fields over the past 20 years has led to increasing national focus on pedagogical reform in science instruction (Augustine, et al., 2006; Fairweather, 2008), and especially to increase minority participation (Astin & Oseguera, 2005; Hurtado, et al., 2008). My primary research question is: Does using a case-based multimedia project affect postsecondary students' learning or motivation to learn biology? I also have 2 sub-questions related to the primary question:

1. Does participation affect students' performance? (i.e. Is there a performance gain?)
2. Based on student comments, do students believe Case It! to be a satisfactory and/or beneficial experience for them?

CHAPTER 3: Methods

This chapter lays out the procedures and methods used in conducting this study investigating the effects of a specific pedagogical intervention designed to improve undergraduate biology education. Specifically, its impact on student opinion and performance was examined. One hundred and five biology students from 5 introductory and upper division classes at 4 universities in the Midwest, Southeast, and Puerto Rico took part in this study. The instructional intervention, Case It!, was comprised of 3 distinct stages, (a) viewing cases, (b) testing and interpreting material from cases, and (c) sharing results and role-playing about the cases.

Because of the complexity of ideas involved in understanding how this particular instruction intervention affected students, I chose to use a mixed-methods design. This design bridges the gap in theory between the traditional constructivist and positivist theories of social research (Johnson & Onwuegbuzie, 2004) and offers the ability to answer complex questions in interdisciplinary studies that do not lend themselves to either research tradition. Proponents of the "incompatibility thesis" of social research design (Howe, 1988) assert that quantitative and qualitative methods are diametrically opposite in their approach to study design and data collection, and therefore completely incompatible with each other. However, beginning in the 1990's some post-modernist researchers began to question the validity of adhering too strictly to one tradition or the other when trying to gain a holistic view of complex questions (Creswell, 2007a).

Rather, they asserted that tools from each research tradition had strengths, and that by mixing their use researchers could view issues from multiple perspectives, which would more likely result in clearer pictures of the issues at hand (Creswell & Clark, 2007; Onwuegbuzie & Leech, 2005). I chose to use mixed-methods in this study because it incorporates the strengths of both qualitative and quantitative techniques (Sechrest & Sidana, 1995), and would help me better understand the impact of Case It!'s alternative pedagogy in greater detail.

Study sites

Study sites included 5 classes on 4 campuses in the Midwest, East Coast, and Caribbean. Of the 5 classes, 4 were 300 or 400 level that focused on aspects of human health. For example, one course was an immunology course that utilized HIV as a main teaching theme, while another was a medical technology class focusing on infectious diseases. The 5th class was a major's level introductory biology course that covered a broad array of topics. Every student taught by 1 of the 5 participating instructors in spring semester of the 2008-2009 academic years was invited to take part in the study. These 5 courses were selected because they were taught by instructors who had helped develop the latest version of the Case It! learning environment, and because they represented a broad cross-section of students in American higher education.

University of Wisconsin-River Falls. The University of Wisconsin—River Falls (UWRF) is a regional comprehensive school located in western

Wisconsin approximately 45 minutes drive from Minneapolis, Minnesota. UWRF is a residential campus founded in 1874, and is 1 of 13 4-year campuses run by the University of Wisconsin system. The town of River Falls is approximately 13,000 people, and the university contributes half again that number with an enrollment in Fall 2007 of 6,007. Even though it has an area of over 220 acres, the main campus feels compact and welcoming. Commitment to current social issues is evidenced by the number of recycling bins, and the new student union, which is a "green" building. Ninety-three percent of students at UWRF are "white, non-Hispanic," 92.8% attend school full time, and 58.4% are women (Integrated Postsecondary Education Data System, 2008). Two biology classes at this site were part of the study, 1 introductory level course (BIOL 150) and 1 majors level (BIOL 345). Of the 50 students enrolled in BIOL 150 Introductory Biology, 86% ($n = 43$) participated in focus group interviews/survey, where 18 were declared biology majors and 25 were non-majors. Thirty-nine students were enrolled in BIOL 345, Immunology, of which 38 consented to participate in focus group interviews/survey (~97%).

North Carolina A&T State University. North Carolina A&T State University (NCA&T) is a residential historically black university or college (HBUC), and a land grant institution established by the second Morrill Act in 1890. The campus is located on approximately 180 acres in North Carolina's Piedmont region. As the state's land grant institution, a primary focus has historically been agriculture; however, the campus also has a growing cellular and molecular biology program. The campus is comprised of over 100 buildings and has been undergoing a $100 million renovation and modernization project since 2002. NCA&T offers 99 degree programs and had a total undergraduate enrollment in Fall 2007 of 9,048 students, of which 91% are African-American, 89.8% are full time students, and 52.2% are female (Integrated Postsecondary Education Data System, 2008). Of the 20 students enrolled in BIOL 401, molecular biology, 6 consented to participate in FGIs/survey (30%).

Interamerican University of Puerto Rico-Metropolitan Campus. Interamerican University of Puerto Rico is a 4-year private university with 11 campuses spread across the island of Puerto Rico. Two campuses participated in this study; San Germán Campus (IUPR-SG) and Metropolitan Campus (IUPR-M). The Metropolitan Campus of Interamerican University is located in the sprawling metropolis of San Juan. It is a relatively small, non-residential, and ill-defined campus of approximately 20 acres hemmed in by expressways and suburbs. There is 1 main instructional building with about 14 smaller satellite buildings surrounding it. Some buildings have a run-down air to them, and a high fence encloses the entire campus as a result of the high crime rate. IUPR-MC was established and accredited in 1962, and offers 119 degrees from certificates to doctorates. The campus is 100% Hispanic, but enrolls more part time students (30.2%) and slightly more women (54.6%) than IUPR-SG. As of Fall 2007 IUPR-M enrolled 6,936 undergraduate students, and 3,674 graduate students (Integrated Postsecondary Education Data System, 2008). Of the 26 students enrolled in clinical immunology, MEDT 4531, at IUPR-MC, only 6 (23%) participated in the FGI sessions due to a number of potentially mitigating factors such as occurring late in day (4:30pm), discomfort with the interview process, and students having just completed a full day of instruction as well as having taken a final exam in a different course that same day.

Interamerican University of Puerto Rico-San Germán. IUPR-SG is a well-defined, midsized residential campus set in a rural area of southwestern Puerto Rico. It is approximately 90 acres and comprises 49 campus buildings. The campus first offered collegiate level courses in 1921, and was accredited in 1944. There is a palpable collegiate atmosphere similar to that found on the campuses of liberal arts schools on the mainland. IUPR-SG is a 100% Hispanic campus that enrolled 4,745 undergraduate students in Fall 2007, of which 52.9% were females and 84% attended full time (Integrated Postsecondary Education Data System, 2008). Of the 22 students enrolled in BIOL 4600, histology, 12 participated in on site focus group interviews (~55%).

Participants

One hundred and five students enrolled in 5 classes participated in this study. The vast majority (75%) of participants were either science majors or post-baccalaureate students ($n = 81$); however, the introductory level course included a large number of non-majors ($n = 27$), who accounted for roughly 63% of participants in that class. Approximately 18.5% of students were Latino, 77.2% were Caucasian, and 5.6% were African-American. Females accounted for 62% of the sample population ($n = 67$).

Every attempt was made to ensure that the participants in this study were accurate representatives of their institutions. In most instances, participants did indeed reflect their site averages (see Table 2). Where measured, participant GPA was not significantly higher than overall GPA. There were roughly equal numbers of participants based on class standing. At 2 of the 4 sites, the male-to-female ratio amongst participants was in line with overall class averages; however, at 2 sites, NCA&T and IAUP-MC, they were not (see Table 2). Males were under-represented at NCA&T, where none participated, but were over-represented at IAUP-MC where half the participating population was male vs. just 16.7% of the total (see Table 2). In all other measured variables, students from these sites accurately represent the central tendency of their class.

Instructional intervention

Case It! is a National Science Foundation sponsored project designed to stimulate learning motivation in biology students by engaging them in the practical application of investigative techniques as related to "real world" problems that may affect them as individuals, such as genetic or infectious diseases (Bergland, et al., 2006). Students author content, view peers' posters, and discuss their own and others' posters with pupils around the globe. Participants work collaboratively in groups of 2-3, and may select a topic that is of interest to them. Each topic area has multiple case narratives from which

Table 2.

Student characteristics for sites overall and by participants.

	UWRF–NM		UWRF–M		NCA&T		IAUP–MC		IAUP–SG	
	Part.[1]	Overall[1]	Part.	Overall	Part.	Overall	Part.	Overall	Part.	Overall
GPA	–[3]	–[3]	–[3]	–[3]	2.80	2.68	3.18	3.00	3.54	3.29
Age[2]	–[3]	–[3]	–[3]	–[3]	–[3]	–[3]	26.7	25.9	22.6	24.0
Class standing										
Freshman	74.4%	76.0%	–	–	–	–	–	–	–	–
Sophomore	20.9%	20.0%	–	–	16.7%	5.0%	–	–	–	4.3%
Junior	4.7%	4.0%	27.0%	25.6%	50.0%	55.0%	–	–	16.7%	13.0%
Senior	–	–	73.0%	74.4%	33.3%	40.0%	16.7%	29.2%	83.3%	78.3%
Post-Bac	–	–	–	–	–	–	83.3%	70.8%	–	4.3%
Gender										
Male	41.9%	44.0%	37.8%	38.5%	0%	20.0%	50%	16.7%	33.3%	30.4%
Female	58.1%	56.0%	62.2%	61.5%	100%	80.0%	50%	83.3%	66.7%	69.6%

[1] Average
[2] Years
[3] Not available

students can select. As part of the Case It! environment, students are involved in using multiple methods of DNA testing, bioinformatics, creating and presenting web posters, and role-playing. The version of Case It! used comprised 3 semi-autonomous functions:

Case It! Simulation Software. This portion of Case It! allowed students to perform virtual lab tests such as gel electrophoreses, western blot, and ELISA in a limited environment (see Figure 1). While allowing students to run these tests, the simulation software also reduces costs associated with the lab tests since expensive equipment and reagents do not need to be purchased.

Mega4 and a separate multiple alignment tool (ClustalW) are bioinformatics tools newly added to Case It! that allow students to analyze DNA they have isolated using the simulation software. This ability permits the construction of phylogenetic trees that graphically depict both the relation of samples to each other and the relative degree of divergence between samples (see Figure 2). Students use these trees to make inferences about the DNA samples, for example to identify if a particular strain of HIV that one individual contracted is related to another sample of HIV in a different individual.

Case It! Launch Pad is a minimal html design tool that allows students to create virtual posters in cyberspace (see Figure 3). Participants are assigned to research and author a web-poster about a human disorder, in the case of this study HIV/AIDS. After viewing/reading different cases about individuals with this disease, students utilize the Case It! software described above. Once the

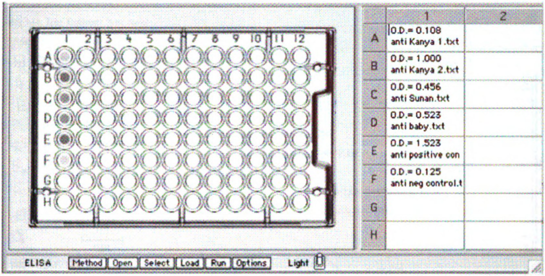


Figure 1. Screenshot of the Case It! simulation software

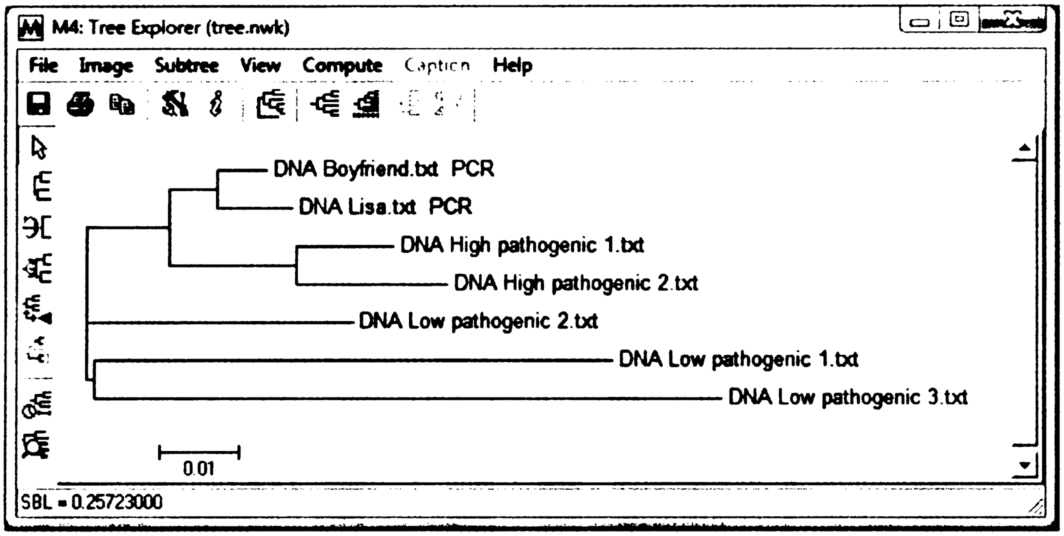


Figure 2. Screenshot of a phylogenetic tree created using Case It! and the Mega4 software.

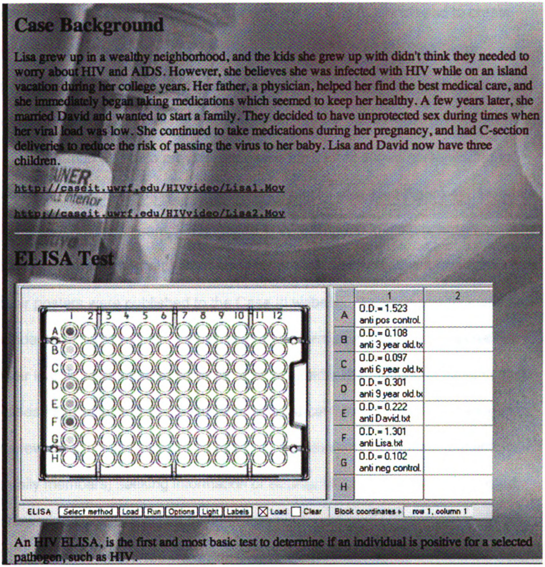


Figure 3. Screen shot of a student created webposter made in Case It! launch pad.

genetic assays were completed, students used Case It! launch pad to create web-posters that incorporate information developed from the 2 software programs and research, and permitted student teams to share their research with others.

Launch Pad also provides an online forum that allows conferencing to occur between and among students from multiple sites (see Figure 4). Students in 3 of the 4 classes sampled engaged in synchronous and asynchronous Internet conferencing with other students at their own and other institutions once their posters were published to the Case It! website. Because of a lack of time, students at IUPR-MC did not participate in a formalized conference as part of their learning experience; however, some students did say they discussed their cases informally. For those students who did conference, each was required to review other groups' posters, to role-play as real-world individuals (patients or family members) seeking information or advice, and in turn pose as an expert answering questions asked by other role-playing students on their topic disease. This interaction occurred via online discussion boards hosted on the Case It! website.

Data collection

Development of instruments. Three data collection instruments were developed and used in this study including (a) a pre-/post-test to examine performance gains, (b) a pen-and-paper student survey intended to explore student opinions about the project, and (c) focus group interviews designed to

Subject: re: Possible Future Treatment
Author:
Date:
Message:
On Wed, Apr 22 2009 10:10:43 PM, wrote:
> On Wed, Apr 22 2009 06:42:11 PM,
> wrote:
> > First of all what specific measures should I take to
> > protect my husband and daughter from acquiring HIV as
> > well? I know that it can be passed through blood and
> > semen but are there any other body fluids that could
> > possibly be a threat?
>
> To protect your daughter, you should not breastfeed her
> because the virus could be passed through breast milk.
> You should buy formula from the store. The best way to
> protect your husband is to practice abstinence; however,
> it's not realistic so you should definitely use condoms
> (make sure they are used correctly) to reduce the chances
> of transmitting the virus to him. Other than blood and
> semen, HIV can be passed through breast milk as well.

I believe protection begins and ends with awareness. Informing your husband of the situation and both of you being proactive about taking care of your body is the first step. abstinence would decrease the risk for him, but is not expected because you are married. Male and Female condoms are very important, protecting you 2 ways opposed to one. HIV can be passed through breast milk, so an alternative method of feeding your child should be considered. Blood, semen, and transmission from the mother to the child are the only ways to contract HIV, so be cautious!

Figure 4. Screen shot of student conferencing via Case It! Launch pad

more deeply probe student perceptions of experience. Pre-/post-test exams were collected by participating faculty; however, I conducted all student surveys and focus group interviews on-site. All data analyzed statistically and qualitatively.

Learning assessment test. A 6-question assessment instrument was re-tooled for use with the current iteration of Case It! by a team of 6 biology professors and 2 education experts at a workshop in River Falls, Wisconsin in early August 2008, and is included in Appendix A. This instrument contained a case study of a couple and their baby tested for HIV. The case presented contained test results from ELISA and Western blots. Students answered questions requiring them to interpret these results, and advise the family regarding treatment. This case analysis task included 6 items worth a total of 26 points that tested: (a) ability to interpret ELISA test results, (b) ability to interpret Western Blot test results, (c) theoretical knowledge of the uses of both ELISA and Western Blot tests, (d) ability to present and interpret the results of both ELISA and Western Blot tests to patients, and (e) ability to interpret a phylogenetic tree to determine the source of infection. A confidence scale was used to measure student confidence in their own knowledge by providing a 5-point Likert scale for each assessment question. After each item, students were asked to assess how confident they were that their answer was correct based on a scale of 1 (very uncertain) to 5 (very certain) (e.g. Lundeberg, Fox, Brown, & Elbedour, 2000).

Initially, the entire test was open-ended, and multiple-choice alternatives were derived from actual student responses for items 1-3. Items 4 and 5 were left as open-ended questions because the development team decided that this was the best method to determine student comprehension of complex situations. A 6th question was added to assess students' ability to interpret phylogenetic trees. Questions 1-5 of the instrument have been used several times previously for publication, but have not been used to specifically test minority engagement and learning in biological contexts. Question 6 on bioinformatics was new, and had not been piloted; however the experts involved in redesigning the test taught at culturally diverse institutions, including an HBUC and 2 Latino institutions, and were asked to keep their own classes in mind as they revised. A Pearson correlation score of 0.263 was computed in SPSS to determine the reliability of question 6 by measuring pre-test vs. post-test scores, indicating unequal reliability; however, Dimitrov and Rumrill (2003) note that the reliability of pre-test/post-test gain scores is *high* when the question does not have equal reliability since such questions are designed to measure performance differences. Therefore, these results indicated that question 6 was reliable. In addition, Wefer and Sheppard (2008) note the field of bioinformatics is so new that neither federal nor state level standards exist. Because there is little consensus on bioinformatics beyond a broad definition, there is little to no availability for tested instruments. Other research in the associated field of problem-based learning suggests that measures do not necessarily have to be previously tested to be reliable (Tarhan & Acar, 2007). The test was specifically designed to be short to accommodate instructors' time constraints (approximately 20 minutes), and to minimize student frustration. It was translated into Spanish for students in Puerto Rico by native speakers and via Google Translate.

Student survey. An 11-question protocol specific to this research study and developed in partnership with 6 faculty members was designed to probe student perceptions of their experience from the perspectives of personal/cultural relevance, intentions to persist, and individual awareness of learning (see Appendix B). Items were developed and refined from: (a) previous interview questions used in past studies of the Case It! project, (b) published literature on student attrition in STEM fields (e.g. Seymour & Hewitt, 1997; Tobias, 1990), and (c) studies of student motivation in the sciences (e.g. Astleitner & Wiesner, 2004; Koballa & Glynn, 2007). Specifically, items asked students about:

1. Future career plans.
2. Whether they believed the Case It! experience helped prepare them for future classes or careers.
3. If the experience reinforced students' desire to be science majors.
4. Topic interest pre- and post-experience.
5. The relevance of the project to students' lives.
6. Student confidence in topic knowledge.
7. The most valuable learning components of the project.
8. Student opinions of the utility of role-playing on learning.

9. Student opinions of role-playing as individuals within the case, and how much they learned be role-playing
10. Whether students felt the learning experience was a good one.
11. Other information students wished to share about the project.

Of the 11 questions, 5 had been used in slightly different form in previous studies of the learning environment. Participating faculty selected, reviewed, and refined questions, serving as both pedagogical and content experts. I revised Items multiple times individually, and with participating faculty as a group. Each question was written as open-ended for inclusion in focus group interviews, and as closed-ended and quantifiable for inclusion on the student survey. Once formatting was finalized, the survey was translated into Spanish via both native speakers and Google Translate.

Focus group interviews. The same focus of the 11 questions used on the student survey were included in the focus group interview protocol, but were restated in a more open-ended fashion in an effort to elicit more detailed student responses (see Appendix C). Where appropriate, follow-up probes were utilized to gain a better understanding of students' thoughts and opinions. Expecting that time would be a limiting factor during interviews, questions were re-ordered to ensure the most important were asked and answered. These items were also translated into Spanish by an onsite interpreter and with the aid of Google Translate.

Collection procedures. Prior to collecting any data from students, consent forms (see Appendix D) were distributed at each phase of research, collected, and kept on file. IRB approval was obtained from MSU (IRB #X07-511) and all 4 research sites.

Learning assessment test. Students took the learning assessment tool (see Appendix A) twice during the semester: once before using the Case It! program, but after lectures on HIV, to establish a benchmark upon which to measure both ability and confidence, and again shortly after completing their Case It! projects. The use of both a pre- and post-test allowed the computation of gain scores and estimations of what students learned beyond lectures. Pre-tests were administered much as student class evaluations are, by volunteer students in class without the instructor present. Exams were sealed in envelopes and given to me upon arrival onsite. Post-tests were either administered by myself when onsite to conduct interviews, or again by a volunteer student.

Student survey. The 11-item student survey was given at the beginning of focus group interviews. Students had approximately 10 minutes to answer, and kept the surveys for reference during the interviews. At the end of each session, students turned in the surveys directly to me.

Focus group interviews. Students were given the opportunity to participate in on-site focus group interviews to answer questions about: (a) their experience with Case It! (b) whether they felt socially or culturally engaged by the project, and (c) the relevance of their chosen research topic to their own lives (see Appendix C). Each focus group interview last approximately 1 hour, with group sizes ranging from 6-12 students depending on overall number of participants. Student sat in a circle around a conference table and freely commented on both my questions and statements made by other students. All focus group interview session were video recorded and transcribed.

Participation was highly variable, ranging from 23-97%. The BIOL 345 class at UWRF had the highest participation rate at 97%, with a total of 38 students participating, divided into 4 focus groups. Over 86% of students enrolled in BIOL 150 introductory biology at UWRF ($n = 43$) chose to participate, also divided into 4 focus groups. Just over half of the students ($n = 12$, 53%) at IUPR-SG chose to participate in a single focus group interview. Approximately 30% ($n = 6$) of all students in the class at NCA&T participated in a single focus group interview. MEDT 4531 at IUPR-MC had the lowest participation rate at just 23%, with 6 students participating in a single focus group interview late in the afternoon.

Data analysis

A collective case study design (Creswell, 2007b; Yin, 2003) was used to compare results across sites. Each site was analyzed individually based on the research questions, and then all 4 were compared and contrasted.

Learning assessment test. I blindly scored all pre- and post-assessment tests for all participants. Closed questions were scored using an answer key, while open-ended questions were scored using a rubric adapted from one used to score previous versions of the exam to minimize the role of subjectivity in scoring exams (see Appendix E). Intra-rater reliability was calculated on open-ended questions. I randomly rescored 27 (~20%) pre- and post-test exams across all 5 participating courses and correlated secondary scores to original scores in SPSS (Wuensch, 2007) to produce a Pearson correlation score of 0.860, indicating a high degree of reliability. Scores were analyzed using SPSS statistical software to generate descriptive statistics, gain scores, and significance tests that were correlated with demographic information collected to create an overall picture of each class. Data were analyzed using repeated measures ANOVA to investigate changes between pre- and post-test performance based on total score for each exam. Additional *post hoc* comparisons were conducted to determine between-subjects effects such as gender and study site. Gain score was also computed for each student from pre- to post-test examination. An item analysis of performance was carried out by ANOVA on overall performance, gender, and site, followed up by independent sample t-tests.

Student survey. I conducted statistical analyses on all closed-ended questions after they were quantified and entered into an SPSS database. I generated descriptive statistics based on overall response to each of the 10 quantifiable questions, assessed gender interactions for each question via independent sample t-tests, and analyzed site interactions using ANOVA. When provided, written answers on the survey were appended to focus group interview transcripts and coded as part of each.

Focus group interviews. I organized data from focus group interviews and open-ended survey questions both categorically and chronologically. This data was reviewed repeatedly, and continuously coded. Transcripts were coded simultaneously utilizing both deductive and inductive coding schemes. To ensure reliability of findings, I blindly recoded 6 of the 11 interview transcripts, including at least 1 from each class. These data were then analyzed in SPSS (Wunensch, 2007) to determine inter-rater reliability, which resulted in a Pearson correlation score of 0.906 and supports a high level of confidence in coding reliability.

Deductive coding. I developed *a priori* codes from prior research on the Case It! project and from the literature on student persistence in STEM programs (Boyatzis, 1998; Creswell, 2007b). Themes included student engagement, personal relevance, interest, motivation, and persistence in field. These themes were revised repeatedly as research progressed and the presence or absence of each was observed in the data.

Inductive coding. As analysis progressed, it became apparent that themes were emerging in the data that were not accounted for by existing *a priori* codes. To address this evolution of themes, open and axial coding schemes (Creswell, 2007b) were utilized to group data into categories and relate them back to pre-existing *a priori* codes and themes. Themes such as denial, bigger picture, and critical thinking were identified in the text of student comments and combined with axial codes developed prior to analysis to create a mosaic of codes.

In general, each student comment was given a single code, although 65 (8.6%) student comments exhibited 2 themes. In such cases the comment was counted for each theme it illustrated. For example, the comment that, "We're just going into a field where you need to make sure that you're thinking about different things, different demographics, and you need to make sure that you're able to put yourself in their [the patient's] shoes," was counted twice because it address both functional science and instructional quality.

Primary coding resulted in several clusters of themes. Upon further review and secondary analysis, I reduced the number of original categories by approximately 68%. Codes deemed to be thematically similar based on both student comments and the existing literature were combined to enhance clarity.

CHAPTER 4: Results

In this mixed methods study, I collected data from both quantitative (pre-test/post-test; student survey) and qualitative sources (focus group interviews). Data were first analyzed as an aggregate whole (case study A) to create an overall picture across all study sites of students' persistence, performance, and opinions. I then analyzed each site individually (case studies B-F) to identify any site-specific differences. Within each site, data were organized by research question.

Case Study A: Cross-site comparison

Student performance. The data from this study show that the Case It! learning environment positively influenced student performance. Students showed a significant gain score over time (see Table 3), and significant performance improvement on questions 2-6 (see Table 4). There were large, significant gains from pre- to post-test for all groups (see Figure 5 & 6), and student confidence in answers increased from pre- to post-tests (see Table 4).

Overall, there was a large, significantly positive increase in performance from the pre- to post-test ($F(1, 80) = 17.256$, $p \leq 0.01$, $\eta^2 = 0.177$; see Table 3). Results show the only significant influence on student performance was time between the pre- and post-tests (noted as "*time*"), with no other combination of factors yielding significant results (see Table 3); however, performance varied significantly by site ($F(4, 80)=4.293$), $p \leq 0.01$, $\eta^2 = 0.177$; see Table 3) As Figure

Table 3.

Performance results of pre-/post-test repeated measures

	F	df Hyp.	df Error	Significance (p)	η^2
Within subjects tests					
Time**	17.256	1	80	0.000	0.177
Time x Gender	0.329	1	80	0.568	0.004
Time x Site	0.164	4	80	0.956	0.008
Time x Gender x Site	0.321	3	80	0.810	0.012
Between subjects tests					
Gender	0.569	1	80	0.453	0.007
Site*	4.293	4	80	0.003	0.177

Note. * $p \leq 0.01$
** $p \leq 0.001$

Table 4.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test (n = 92).

		Pts. poss.	Pre-mean	Post-mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.565	2.663	1.059	0.098
Q2	Interpretation of Western Blot results	4	3.272	3.380	1.043	0.109
Q3	Comparison of ELISA vs. Western Blot	7	3.533	4.152	1.796	0.620**
Q4	Application of results in counseling parents	4	1.692	2.055	1.295	0.363*
Q5	Application of results in counseling about child	4	0.890	1.407	1.089	0.517**
Q6	Interpretation of bioinformatics results	3	0.727	1.193	1.050	0.466**
		Pts. poss.	Pre-mean	Post-mean	SD	Δ Confidence
Q1	Interpretation of ELISA results	5	3.033	4.033	1.095	1.000**
Q2	Interpretation of Western Blot results	5	3.444	4.122	1.235	0.678**
Q3	Comparison of ELISA vs. Western Blot	5	2.667	3.611	1.021	0.944**
Q4	Application of results in counseling parents	5	3.122	4.022	1.181	0.900**
Q5	Application of results in counseling about child	5	3.102	3.841	1.199	0.739**
Q6	Interpretation of bioinformatics results	5	2.317	3.266	1.250	0.949**

Note: * Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$

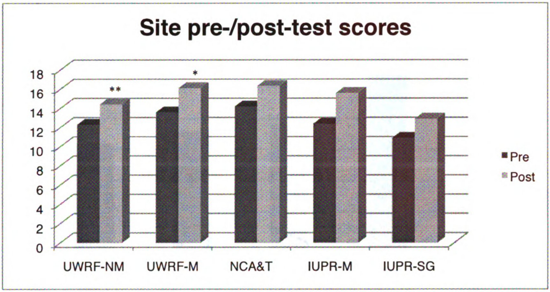


Figure 5. Student performance means by site.
Note: ** = significant at $p \leq 0.05$ ($t(25)=2.599$, $p=0.015$)*
*** = significant at $p \leq 0.001$ ($t(41)=4.265$, $p=0.000$)*

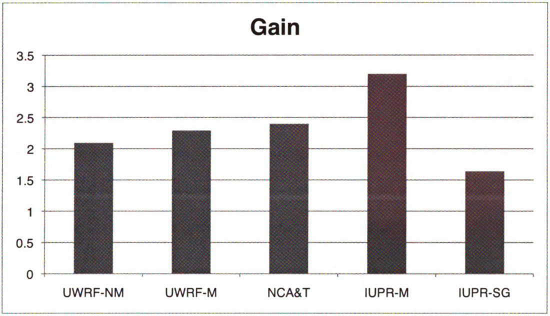


Figure 6. Average student gain from pre- to post-test based on site
Note: No significant differences in performance gain based on site.

5 shows, there were significant improvements in performance by site. Although there was an overall significant improvement in performance, the site-by-site analysis demonstrated that the two classes at the University of Wisconsin–River Falls significant improved from the pre- to the post-test (see Figure 5). However, as Figure 6 shows, there was no significant difference in gain score between sites. Given this, it is likely that the low sample sizes at the other three study sites resulted in a lack of significance. Figure 7 shows that there was uniform improvement over time.

Table 4 shows that participants demonstrated significant improvement from the pre- to post-test on test items 3-6. Ceiling effects may have come into play on item 2, interpretation of Western Blot results, as both the pre- and post-test scores approached the maximum points possible (see Table 4). It is interesting to note that student confidence in their answers increased uniformly and significantly from pre- to post-test, *even when their scores did not significantly increase* (see Table 4).

Overall, there was no significant performance difference between men and women (see Table 3). Table 5 shows that gender was a significant factor in only 2 of the 12 pre-/post-test questions, pre-test questions 1 and 5. On average, men performed significantly better than women on pre-test question 1 ($F(1, 102)=7.342$, $p \leq 0.01$), whereas women outperformed men on pre-test question 5 ($F(1, 101)=9.489$, $p \leq 0.01$). An item analysis of performance results showed that

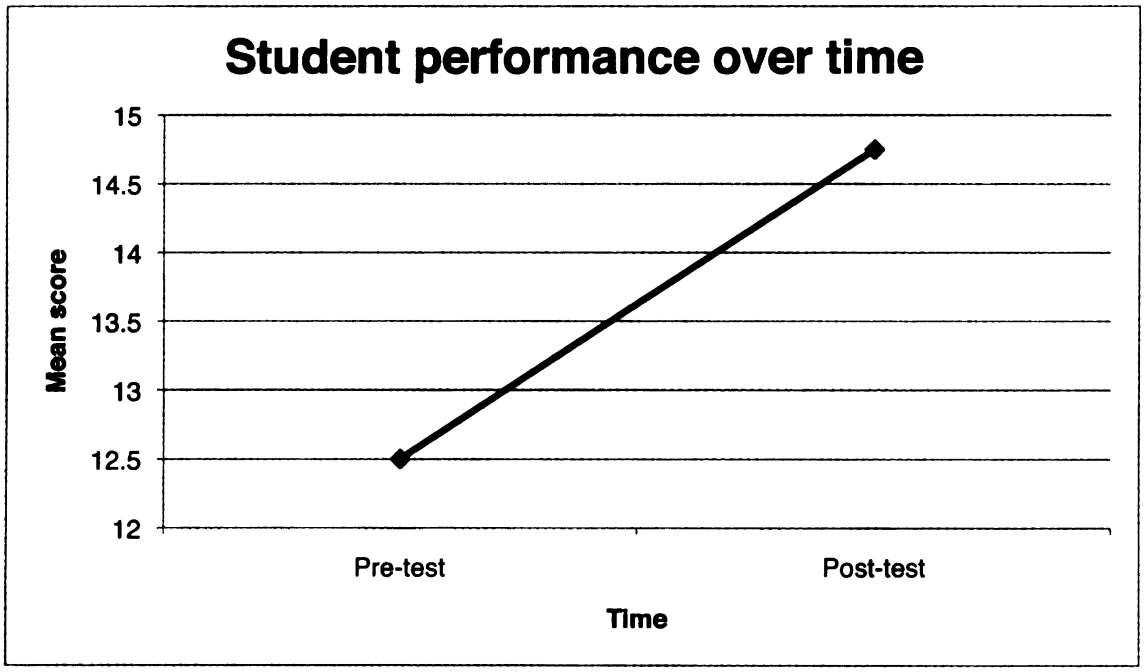


Figure 7. Student performance means over time.

Table 5.

Question-by-question analysis of pre-/post-test questions by gender and site.

			Pre-test				Post-test			
				df				df		
			F	Hyp.	Error	Significance (p)	F	Hyp.	Error	Significance (p)
Q1	Interpretation of ELISA results	Gender	7.342	1	102	0.008 (1)				
		Site	–	–	–	–	8.378	4	96	0.000 (4)
Q2	Interpretation of Western Blot results	Gender	–	–	–	–	–	–	–	–
		Site	–	–	–	–	–	–	–	–
Q3	Comparison of ELISA vs. Western Blot	Gender	–	–	–	–	–	–	–	–
		Site	–	–	–	–	–	–	–	–
Q4	Application of results in counseling parents	Gender	–	–	–	–	–	–	–	–
		Site	–	–	–	–	3.900	4	95	0.006 (5)
Q5	Application of results in counseling about child	Gender	9.489	1	101	0.003 (2)	–	–	–	–
		Site	–	–	–	–	4.213	4	95	0.004 (6)
Q6	Interpretation of bioinformatics results	Gender	–	–	–	–	–	–	–	–
		Site	3.900	4	99	0.006 (3)	4.904	4	93	0.001 (7)

Note: (1) = Men performed significantly better than women
(2) = Women performed significantly better than men
(3) = UWRF-M performed significantly better than UWRF-NM and IUPR-SG
(4) = NCA&T performed significantly better than all other sites. UWRF-NM performed significantly better than UWRF-M. IUPR-SG performed significantly better than UWRF-M
(5) = UWRF-M performed significantly better than NCA&T, UWRF-NM, and IUPR-SG

location was a significant factor affecting 4 of the 12 pre-/post-test questions. On pre-test question 6, students in UWRF-M performed significantly better than pupils in UWRF-NM or IUPR-SG ($F(4, 99)=3.900$, $p \leq 0.01$; see Table 5). Students at NCA&T performed significantly better than all other sites on post-test 1 ($F(4, 96)=8.378$, $p \leq 0.001$; see Table 5), while participants at UWRF-NM performed significantly better than UWRF-M, and those at IUPR-SG performed significantly better than UWRF-M. On post-test question 4, students from UWRF-M performed significantly better than those from NCA&T, UWRF-NM, and IUPR-SG ($F(4, 95)=3.900$, $p \leq 0.01$; see Table 5). Students from both UWRF-M and NCA&T performed significantly better than those from UWRF-NM and IUPR-SG on post-test question 5 ($F(4, 95)=4.213$, $p \leq 0.01$; see Table 5), but not versus each other. Finally, on post-test question 6, students from UWRF-M performed significantly better than NCA&T and UWRF-NM ($F(4, 93)=4.904$, $p \leq 0.001$; see Table 5), and students at IUPR-M performed significantly better than UWRF-NM.

Student intentions to persist. Overall, the use of the Case It! learning environment did appear to have a buttressing effect on student desires to persist in their declared major. Students repeatedly iterated in focus group interviews that the project reinforced their intentions to be science majors and validated their career and/or course objectives. The multimedia, case-based learning environment created an overall context for material from multiple classes that allowed student to fit all the pieces of their previous academic instruction together into a single, comprehensive picture—and to place themselves within that picture.

Prior to conducting the study, several themes were identified as proxies for student persistence based on the literature. Based on this list, and on emergent coding, 5 themes related to persistence surfaced in student comments across the study sites (see Table 6). Comments related either directly to student persistence or persistence proxies accounted for just over 47% (n = 548) of all statements from focus group interviews and surveys (see Table 7). The overall picture presented was that Case It! did influence retention, and students expressed an intention to persevere. Parametric statistics conducted on answers to the student survey support this, demonstrating that on the whole, students moderately agreed that Case It! reinforced their desires to be science majors (M=3.304; scale 1-5). Over 87% of students agreed that the project would help them with future classes or careers, while 59% found it relevant to their lives. Students like Noah said that it was, "...definitely a reinforcement..." while others like Olivia and Emma thought the experience, "...helped me realize that I want to go into the medical aspect of biotechnology and science," or that it, "...reinforced my career choice..."

Instructional quality. Table 7 shows that 250 (21.6%) student comments were coded as referring to the overall instructional quality of Case It! Of these, a few were generalized statements or opinions about instruction, and generally positive, like those expressed by Gavin who said, "[Case It!] just...pulled it all

Table 6.

Definitions and examples of codes

Category	*Description*	*Example quotations*
Intentions to persist		
Instructional quality:	Statements or opinions about instruction, personal connections with the material, increased interest, or a preference for cases.	"I just liked that it was a different approach to it. You know, every other class, you sit there in lecture and you take notes. And this is what you do, day in and day out…"
Role-playing:	Comments about the utility of role-playing, liking the dialogue developed during role-playing, acting as an instructor, student-to-student interaction.	"It was fun. I kind of felt like I was House [M.D.], curing people."
Functional science:	Response to specific vocational or potential needs. Comments about careers—content valid to students' futures, goals, or lives.	"…It's like some practice, if you will, for future life—kind of a real-life situation."
Self-efficacy:	Comments related to acquiring knowledge to become the expert, to understand experts, or to understand science.	"[The material is] going to stick now. After the end of the semester, I'm still going to be able to remember this."
Community/integrated into science:	Comments about community building, interactions, or about feeling more integrated into the culture or society of science or scientific inquiry.	"It…makes you feel like you are a doctor."
Beliefs:		
Diagnostic testing process:	Statements about specific tests, interpreting results, or bioinformatics.	"I think it reinforced…the diagnostic tools—not necessarily like the ELISA part—but like how it works, and what we've done in lab and stuff…"
Learning:	Comments about learning, the applied use of theoretical ideas, autonomous research, or analytical reasoning.	"…There's always something to learn. There's always new discoveries. You just have to keep up with your learning."
Science content:	Comments about disease, treatment, or transmission.	"It helped get some more insight on HIV—the virus itself—from the project."

Communication:	Comments related to communicating effectively with scientists or explaining scientific content in lay terms.	"I think that the overall goal was to learn how to communicate…"
Multiple perspectives:	Transfer of knowledge between subject areas. Seeing connections, seeing things in a different light, or from multiple perspectives. Ethics.	"[Case It!] brought all [the] pieces together that we learned in a science class at like the molecular basis, and how the virus worked, and what happens."
Stigma/Denial/Misconceptions:	Statements related to students' beliefs that diseases either cannot affect them, or will not.	"Right now it doesn't really affect me. I don't know anyone with AIDS—at least no one's said anything about it."
Turned off science:	Comments related to feeling alienated by science or of decreasing interest. Primarily presented as dislike of laboratory or the use of computers.	"[Case It!] has kind of reinforced that I know I don't want to do research. It's kind of interesting, but I don't necessarily like doing it."
Need-to-know:	Response to specific decisions or problems in life.	"At first I wasn't really happy about doing [HIV], but during the semester someone in my life has been diagnosed with HIV, so it's helping me understand the disease a lot."

Table 7.

Categories of comments and their aggregate instances across all sites (n =1160)

Category	*n*	%
Intentions to persist	**548**	**47.07%**
Instructional quality:	250	21.55%
Functional science:	116	10.00%
Role-playing:	99	8.53%
Self-efficacy:	60	5.17%
Community/Integrated into science:	23	1.98%
Beliefs:	**612**	**52.76%**
Diagnostic testing process:	160	13.79%
Learning:	132	11.38%
Science content:	116	10.02%
Communication:	70	6.04%
Multiple perspectives:	61	5.26%
Turned off science:	27	2.33%
Stigma/Denial/Misconceptions:	26	2.24%
Need-to-know:	20	1.72%

Note: Percentage calculated by [n(category) / total n]

together," or William who reported Case It! "...kind of ties everything together in one thing, even what you learned in lecture and other wet labs." Kira reported that, "...it helps to actually apply what you're learning in class, like we did with Case It! and be able to understand it more..." Kira also said that she enjoyed that the structure of instruction was different saying,

> I just liked that it was a different approach to it. You know, every other class, you sit there in lecture and you take notes, and this is what you do, day in and day out, and the same with lab. But this is just a different approach. I've never taken a class that used the technology in this way, so it was interesting.

However, a few students like Aaron said, "...I just didn't get into it. It seemed kind of artificial to me, and a little bit forced," indicating that the methods utilized by Case It! were not universally relevant.

For many Case It! created a bridge between content and their private lives by making cases personally relevant to them. This attitude is typified by Leah who said that,

> ... it made me feel more like a personal connection with them [the patients in the cases]... since it was a true story, I was able to get a better connection with doing the Western Blot and ELISA and being able to speak to them.

Beth seconded this opinion stating that, "...I think actually reading the case studies of people's actual lives, people that are affected by it, makes it more human and less of something that like you learn in science class..." A feeling of personal responsibility to the characters in the cases was frequently cited as a reason for exerting greater effort on the project, as demonstrated by Emma who said, "...when we got to the actual personal cases with it, you wanted to do it more because you want to find out for those people..." Other students like William said that the personal connections created were important because, "...when you can see a name or a face to relate that to it makes it more real."

An example of how information from this project can affect students' private lives is evidence by Zoë who said that, "At first I wasn't real happy about doing it, but during the semester someone in my life has been diagnosed with HIV, so it's helped me understand the disease a lot." Ashley extrapolated her experiences to her future stating,

> ...I also think [Case It!] helps in personal life if you've a friend or loved one that's going to have to deal with this disease—you're going to be able to hopefully take the knowledge that we've gained through here and be able to put yourself in...their shoes...

Leah took a slightly different view of the same issue when she said,

> ...[Case It!] was just real personal, and—well, down to earth I guess—but, just to be able to possibly relate to these people, and to know that these cases *are* real, and that you *could* get it, just made it—made Case It! more fun to work with...

Many students expressed empathy for those involved with the cases, like Ashley who said, "...you're going to be able to hopefully take the knowledge that we've gained through [Case It!] and be able to put yourself in...their shoes, and be...more understanding. And do the empathetic thing and be there for them." Zoë echoed this sentiment saying, "...[Case It!] helps me understand what the person is going through." Alice said that, "... the personal lives of these real people...[make Case It!] relevant," demonstrating that using real individuals, not made-up characters, led some students to find greater relevance and importance in the material. Emma said the same feeling was true for her because, "...when we got to the actual personal cases with it, you wanted to do it more because you want to find out for those people..."

Students also made comments to the effect that Case It! either stimulated their interest in health, or that it made them eager to learn more. Most student comments echoed those of Olivia who said, "I found [Case It!] really interesting," or Maggie who said, "I just thought it was cool!" However, some students were more specific as to what had stimulated their interest, like Carrie who said that the personal connection to the material, "...just makes a lot more real. It just makes it more interesting." Maggie was very excited about the project, telling me at another point during the focus group interview that she was, "...definitely more interested in HIV and AIDS than I was before—just 'cause there's so much to learn." Leah was perhaps the most specific when she said, "... actually being able to do [ELISAs and Western Blots]...helped me understand it better, and I became more interested...Being able to do it made me appreciate it more."

Functional science (related to future work). Many students said that they found the Case It! experience to be directly relatable to their future *professional* lives whether that be in healthcare, research, biotechnology, education, or any other of myriad options. Overall, health related career paths were the most popular choices for student overall, and by gender. There was significant agreement by students ($\chi^2 = 46.05$; $p = 0.000$) that Case It! helped prepare them for future classes or careers.

As a category, functional science is defined as that knowledge needed for specific, *vocational* purposes, and so it is not surprising that given the disproportionate number of upper division classes in this study about 10.0% (n = 116) of all student comments were coded here (see Table 7). Some students reported that the experience helped them better envision or prepare for their futures, like José who said, "... you [see] how you can relate...life on the outside with what you are going to do in your job," and Olivia's comment that, "[Case It!] actually did help a lot...it helped me realize that I want to go into the medical aspect of biotechnology and science." Kathy said, "...it helps you when you think about a career and what you want to do." Autumn was more direct, simply averring that, "I definitely think [Case It!] helped prepare me for a career," and that she thought, "...more than anything else, the counseling and role-playing really help prepare for a lot of future careers that some of us are planning on having..." Others reported that Case It! provided them with a real-world environment in which to practice applying theoretical knowledge acquired in this and other classes. This is exemplified by Eli's comment that,

> I...have to say that [Case It!] helped with future careers, or future classes, because not only does it emphasize new things that researchers, or even just biology majors, might go through later on, but you can use this knowledge in different classes that come up...

Neil reinforced this perspective saying that, "...it's like some practice if you will for future life, kind of a real-life situation..."

Other students reported that a real benefit of Case It! was that it served to reinforce decisions students already made, but may have questioned. This sentiment is illustrated by comments from Noah who said, "I definitely think it was a good introduction to research…" and "…I'm also going to be doing research, so this was definitely a reinforcement for me." Emma said that Case It! had, "…reinforced my career choice…" while Kim simple stated that, "This will help me in the future."

Role-playing. Of student comments in focus group interviews, 8.5% (n = 99) were coded as role-playing (see Table 7). Overall, students moderately agreed on a Likert scale of 1-5 that role-playing helped them learn (M=3.526). Several students said that participating in role-playing forced them to look at problems from multiple angles and engage in analytical thinking, like Katie who said that,

> …role-playing and conferencing…really forced me to think critically about the results that we had from our cases, and forced me to think about them in a different light so I'd be able to explain them to whomever was asking us questions…

Autumn seconded this position saying she, "…enjoyed the aspect of role-playing a lot, and seeing from a different perspective. It made me more interested in looking at the different groups of people that it affects and how it affects their families as well." Kim cross-referenced role-playing with empathy when she said, "…role playing is another good [part of Case It!] because you really got to go into the mindset of the person going though this." Other students enjoyed the ability to step into another person's life, such as Neil who said that role-playing was, "…like getting into someone else's shoes, or at least trying," and Lisa who reported that, ...the role-playing was really cool for me because I can really get into somebody else's shoes, and think like I think they would think."

Over 20 students said that they enjoyed the dialogue of questions and answer that arose from being required to role-play as both doctor and family member. Students said that this discourse caused them to be more contemplative, like Winnie who said that, "...its good to just sit down and think about [HIV] and ask more questions." Others, like Jarred, said it caused them to consider the questions they were asking from new or different perspectives, stating, "Some times when you were role-playing, and you're asking the questions, you had to think, 'Well, if I really had this, what would *I* want to know. What would be my questions?'" This connection with codes in the bigger picture category is reinforced by Leah's comment that she was,

> asked questions that I didn't even think about. And then the way how we had to ask questions like if we didn't have a biological background, I think that helped, and it also made me aware of the information that I knew because I was able to answer the questions.

Pupils also identified the need to answer very specific and directed questions during role-playing as a reason for conducting deeper research, like Autumn who said, "I think it helped to learn because if they asked question that you actually didn't know, well then you had to go and look for the information and learn it that way..." Kira reiterated this perspective stating, "...[we] had a question that we hadn't thought about in that way, or it was about one of the tests that we didn't cover, so we had to figure it out."

Other students reported that the best part of the role-playing experience for them was the opportunity to teach others in the role of either physician or genetics counselor. Sometimes these comments were linked to additional research, like Gavin who said, "I liked also the role-playing, more so being the one answering the questions because it made you go into more depth because you thought well if they asked this question but then what about this...?" Ashley said that,

> I think I learned more because I was able to break it down, to make it simple, to say "This is this, and that is that." For me at least, I've always been able to learn more when I teach, so I think I did learn more when I had to break it down.

A vocal number of students were adamant in their support of conferencing between peers as a useful component of Case It! A number of students said that questions asked in conferencing helped them view questions and issues from different perspectives, like Tanisha who said,

> I just think its always interesting to see what other people think, because you could give us all the same book and we'd all say different things about it, so I think its pretty cool to just see how they thought about their case...

Associated with this idea was Leah's comment that, "...[Other students] asked questions that I didn't even think about." One student, Kevin, was expressive when he cautioned others on the difference between role-playing and conferencing, telling me,

> Role-playing was useless. I know that's very blunt and frank, but I think that a lot of people are confusing the conferencing with a role-playing. Conferencing, very beneficial—scientists talking to each other, discussing the disease—great way to learn. Me pretending to be Lisa's husband, and

> asking, 'What do these results mean?' when I know the answer is not useful.

Earlier in the discussion, Kevin expressed his favor for peer-conferencing when he said, "I really like the conferencing—just anytime you have discussion it leads to more knowledge than to somebody telling you something." At least one other student, Jarred, was thankful for the opportunity to conference with his peers because,

> You can also maybe act like a person that has the virus, and so maybe if there's something you're not too sure of, and you don't really want to ask it in front of the class, that you can kind of like be, "Hey! I'm Maria. I was just wondering this. Do you have an answer?" Then people wouldn't know that you really don't know stuff.

Building self-efficacy. An appealing component of Case It! for some students ($n = 60$, 5.2%; see Table 7) was the opportunity to demonstrate the depth of their knowledge, or to be the expert in a pseudo-professional situation. This is borne out by the fact that overall, students said they felt confident in their knowledge of science content (M=3.925; scale of 1-5), and could apply that knowledge autonomously. Greg said, "...its kind of cool that you get to be somebody else, and you get to act like you know what you're doing—you get to act like the smartest one." Katie seconded this opinion stating, "...you can think to yourself, 'Oh, I would be the expert in this situation.' And, it's a little strange, but pretty cool at the same time." Other students focused their comments more on their own knowledge acquisition and personal development, like Neil, who said, "...[before] I knew of [HIV], but not about it. Now I feel like I can field general questions about it, and point someone in the right direction to get an answer." Comments such as Greg's when he said, "[The material is] going to stick now. After the end of the semester, I'm still going to be able to remember this." illustrate that some students felt participating in Case It! cemented knowledge beyond what they felt was typical for class.

Feeling like a scientist (Community/Integrated into science). One of the benefits of participating in Case It! that students cited was that it made them feel either like members of a community of scientific scholars, or integrated into the culture of science and scientific inquiry. A total of 23 comments (~2.0%; see Table 7) were coded into this subcategory. These included opinions about feeling like a "real doctor" as evidenced by Caesar's statement that, "[Case It!] lets you see what is happening, and it makes you feel like you are a doctor," Tanisha's belief that, "…I think that part of the case made it more like you were actually a doctor…" and Greg's laughing remark that, "…I kind of felt like I was House [a popular television doctor] curing people." Other comments indicated that students felt the encounter gave them virtual experience as a professional in the field, like Catherine who said that, "…we were able to basically be the doctor, or the lab technician, and say, 'Yes this person has it. Or no, this isn't. Or, you might need to retest.'"

Student beliefs. Students overwhelmingly thought that Case It! was a good learning experience for them, with 95% responding positively to the question on the student survey. The most frequent reason given for this was that the project made the material "real" to participants instead of just abstract or esoteric facts shot at them in a lecture. Students made personal connections with the material. For some, this manifested as altruism where participants felt a sense of duty to the individuals portrayed in the case studies and obligated to help them, even though the situation was constructed. Other students said that they developed a sense of empathy for the patients as the project progressed, and because of this felt more connected and that the information was more relevant to them.

The majority of students (59%) found the project to be relevant to their lives, and as a group thought their experiences had made them more confident in their knowledge (M=3.808). Participants also reported a significant increase in interest from before to after Case It! ($t(106)=9.894$, $p \leq 0.001$). Figure 8 shows that the two most popular aspects of the project overall were the virtual lab and conferencing aspects, although opinions varied by gender and site.

As with the previous section on persistence, codes and themes related to student beliefs were identified prior to conducting the study. These were combined with emergent themes to yield 8 categories of student beliefs about the project (see Table 7). Comments in these categories accounted for roughly 53% (n = 612) of all student statements.

Diagnostic testing procedures. As shown in Table 4, a large number of comments (n = 160; 13.8%) indicate that students said the speed at which results were returned, and the number of different tests available contributed significantly to both their enjoyment of the Case It! environment and their learning. Tanira

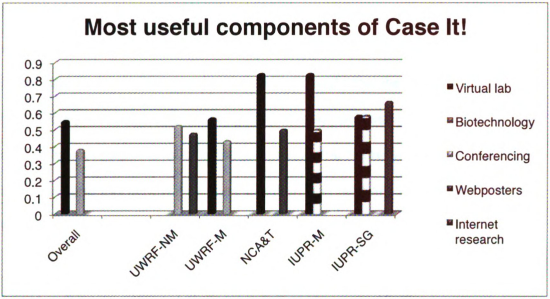


Figure 8. Student ratings of most useful Case It! components.

demonstrated this attitude when she said, "I enjoyed how easy [the virtual lab] was to learn…and how fast and easy it was. I liked that I could see the process in the virtual lab…" Other students like Kira thought that the virtual lab was a good focal point because, "…having to go through process of…figuring everything out helped a lot…" while Gavin said that "…the virtual lab…was quick and easy, and this is how it all goes together, and here are your results, and here you analyze it…"

The concept of bioinformatics, the employment of technology to inform life sciences, was new to most students in this study. Jarred typified many students' opinions on the topic, "Bioinformatics? I didn't really know a lot about that. This is the first time that I've heard about it, so I've actually learned quite a bit about that." Overall, students appear to have felt that Case It! provided a good environment in which to explore bioinformatics, as demonstrated by comments from Nicole that, "…Case It! made it easier to do bioinformatics…" and Maggie that, "…I just thought it was really interesting that someone could create a phylogenetic tree and say, 'Well, this is how your virus is related. This is how you got it.'"

Several students said that they appreciated not only the ability to quickly develop results from various molecular tests, such as ELISA, Western Blot, and Southern Blot, but also to accurately analyze those results. Kevin exemplified this position when he observed that, "…[Case It! gave us] the experience and the results part—where we got the results—we know how to analyze the results. I think it was a lot more beneficial than doing the physical experiments." Catherine added her voice, stating that she, "...definitely felt the most beneficial part was understanding the results..." Other students like Aaron were less specific but still adamant on the usefulness of Case It! in providing and interpreting results when he said, "I liked being able to look at the lab results. Most people don't take the time to explain it, and I think that's really important."

Learning. Comments that made either broad reference to scholarship, or described specific techniques were coded into the learning category (*n* = 132, 11.4%, see Table 7). Many students had specific opinions on how Case It! impacted their knowledge base in relation to application, conducting additional research, and critical thinking. However, others expressed themselves more generally, saying that Case It!, "...helps you visualize what you need to do," (Caesar), or "...[Case It!] did a lot of reinforcing..." (Rachel).

Some students said that Case It! created a hands-on learning situation where they were able to apply theoretical knowledge in practical situations, which was more interesting and engaging to them. Daniel said that, "You got to apply the theory. It was like a hands-on training—a lot of understanding, not just reading and reading," while Kira said that, "...it helps to actually apply what you're learning in class, like we did with Case It! and be able to understand it more..." Several students said they enjoyed working with Case It! because it was based in practice, like Tanisha who said, "...when you read it in a book, you can't really get the hands-on feeling, so Case It! allowed you to do that," and

Aaron's statement that he, "…got to take theoretical information and turn it into applicable knowledge…which you don't get to do very much in classes…" Margerie was emphatic when she said that, "When you practice it is not the same as in the books—the experience is completely different." Greg appreciated the chance to, "…apply my knowledge…"

Other students said that the hands-on nature allowed them to make connections between different aspects of the learning environment, like Jarred who emphasized his enjoyment of being able to put theory to practical use when he said, "…[I] see real life application of the ELISA, and the viral load, and bioinformatics being put into application." Greg's comment that, "…it's gonna stick now. After the end of the semester, I'm still going to be able to remember this," demonstrates that students also felt that what they learned from Case It! would persist beyond just the end of the class.

A frequent comment was that Case It! encouraged autonomous learning and stimulated personal discovery and interest. Conducting additional, independent research was linked by some students, like Kevin, to a deeper connection with the material when he told us that, "…once you start reading people's questions…you have to start looking up stuff and that makes you learn more about the disease, and you find out things that are interesting." The idea that additional research can act as a catalyst to generate interest is further supported by Rachel's comment that she, "…think[s] that was beneficial because then it just has sparked your interest in you to do further research," and Kathy's statement that, "...[Case It!] helps me out with other diseases and it might encourage me to go out and do more research not necessarily on AIDS, but maybe on other types of infectious diseases..." Greg liked the fact that he had the opportunity to conduct further research, telling me that Case It!, "...gave me time to remember things and look stuff up on the internet."

A few students thought that Case It! helped stimulate analytical processes. Ashley is a good example of one of these students. She said, "I think I learned more because I was able to break it down—to make it simple—to [be able to] say, 'This is this, and that is that.'" Other students like Katie said that,

> ...role-playing and conferencing...really forced me to think critically about the results that we had from our cases, and forced me to think about them in a different light so I'd be able to explain them to whomever was asking us questions,

while Catherine commented that, "...this experience gives us the analytical aspects of biology, so we're more able, and prepared..."

Science content. Just over 10% of all student comments were coded as science content items (*n* = 116; see Table 7). Many students expressed their experiences with Case It! through the lens of content specific to a disease. Neil's statement that, "[Case It!] helped get some more insight on HIV, the virus itself..." is typical of this perspective.

Students mentioned the treatment of disease on several occasions in the focus group interviews. These comments appear to have come predominantly from those pupils intending to pursue careers in health related fields like nursing, medical technology, and primary care, and are typically associated with some form of surprise or developing interest on the student's part. Eli's comment is a good example of this. He stated that, "…I think I am more interested in the pharmaceutical control regimen of HIV. I didn't know anything about that, or how it worked—anti-retroviral medication." Many females students expressed empathetic undertones to treatment, like Ashley, who said that, "…I really had no idea about the treatments and the drugs that they had out there that were, not actually curing it, but giving some hope and a potential for a brighter future," and Heather, who said, "…the treatment options were really interesting…I saw the different combinations, and you're not just taking one thing. You're kind of hitting it [HIV] at different angles."

The transmission of HIV or how genetic disorders develop were not subjects that arose frequently; however, some students were detailed in their appreciation of how Case It! helped them better understand this aspect of a disorder. An example is Leah's comment that, "…it was interesting to know that just because some of the cases were in the U.S., and some were in Africa, they all contracted the same way, no matter what you're doing, or who you're with…" which also alludes to the codes, misconceptions and learning. Another student comment that evidences interactions with other codes is Eli's when he said, "Because of having to research everything, we actually had to learn how it infects and what can actually go on during the infection—the infection cycle and everything."

Communication. As shown in Table 7, a number of student comments (*n* = 70; 6.0%) indicated that students found Case It! engaging, useful, or relevant because it required them to develop the skills to communicate effectively with both patients and scientists. Some of these comments dealt directly with the ability to convey ideas and converse with specialists on a professional level. This was demonstrated by Catherine's comment that, "…we're more able and prepared to go out and be in the lab situation or doctor's office, and be able to know what's being presented in tests…" Another student, Kevin, said, "I think that the overall goal was to learn how to communicate, and [to] learn how to interpret the test results…"

The vast majority of comments coded as communication dealt with how to relate or interpret scientific results for the layman. These comments generally hinged either upon the idea that one would be required to perform such duties within the normal scope of one's job (e.g. as a nurse), or upon the realization that students may not have considered effective communication of complex ideas to be an issue prior to participating in Case It! The former idea was exemplified by Carly's comment,

> I thought that…answering questions from each other, was the most important because…on a professional level, as medical interpreter, I'm sure I'm going to encounter patients who have tested positive, and I'm going to have to know how to talk with them professionally…

Katie's comment illustrated the latter idea when she said, "…role-playing and conferencing…forced me to think about [cases/HIV] in a different light so I'd be able to explain them to whomever was asking us questions—explain them in the simplest forms so they would understand." Another student, Rachel, bridged the two ideas, telling me, "I think it like helped us with bedside manner, and being able to show compassion for people who are…you know these are people who've had their worlds turned upside down with some of these diagnoses…"

Multiple perspectives. Knowledge frequently has applications outside the context in which it was learned, and several students commented on this fact during the focus group interviews (n = 61, 5.3%; see Table 7). Comments in this category link to an emerging branch of biology, called *systems biology*, that seeks to emphasize and accentuate connections between subject areas, promote the development of multiple perspectives on issues, and create discourse around ethical dilemmas. Teresa's comment illustrates the application of this concept within Case It! almost verbatim when she said, "…it helped us make connections between different areas of science that we maybe hadn't thought of before…"

A number of students said that participating in Case It! forced them to look at issues from multiple perspectives that they otherwise might not have considered, or even known about. Niña gave voice to a common example echoed across sample sites when she said,

> I worked on the young African woman [Catrice] who was a young mother, and I learned that not only was it her family that her HIV affected, but also others [in her community] were affected by the results of the test. I'd never really thought about either…

Jarred said that, "You definitely learn how to take others' perspectives on things, meaning patients and also the counselor side of things, and how to talk with both when you're doing the conferencing." Gavin said that the autonomous nature of the learning environment helped him see connections, stating that, "...you just go off on tangents, and then you further your knowledge and understanding of AIDS, and how it impacts the world around us..." Several other students made similar comments about how unique an experience it was to view what they considered to be a biological issue from sociological and cultural perspectives, and how that helped them develop a more holistic lens with which to view the problem of HIV. Neil summed up his experience with Case It! saying,

> ...there's so many people involved in studying a case like HIV, there is...not one person who does it all. And for you to be able to get insight into a little bit of what everyone involved in a case does was helpful. Just an all-around picture...

Jarred reiterated this sentiment, stating that, "It was really nice to see [the application of ideas] instead of just reading about it and kind of hearing about it. It was good to kind of see it all happen." A few were more succinct, like Tanisha, who simply said, "...[Case It!] allowed you to see the bigger picture."

Turned-off science. Some students said that their experience had soured them on specific aspects of science ($n = 27$, 2.3%; see Table 7). It is important to note though that none of these students expressed a desire to leave the biological sciences as a result of this experience, but rather an intention to re-direct their focus into areas more compatible with their personalities, such as medical counseling. Three students made comments that their experience with Case It! had confirmed to them their dislike of laboratory settings, tests, and procedures. This attitude is demonstrated by Heather who said, "It kind of reinforced that I know I don't want to do research; as it's kind of interesting, but I don't necessarily like doing it."

A few students (n = 11) made comments about being uncomfortable with, or disliking the use of, computers. Generally these comments were not associated with specific biological principles of procedures, but fell more into the category of technophobia, as illustrated by Rachel's comment that, "...I wasn't too fond of having to work on computers 'cause they are not my thing."

Stigma/Denial/Misconceptions. Few health subjects are as culturally and socially charged, or as surrounded by misconceptions, as HIV/AIDS. As such, it is not surprising that some student comments (n = 26, 2.2%; see Table 7) were coded as stigma/denial and misconceptions. In general, comments were in reference to (a) social stigma associated HIV, (b) personal denial that infection could be a real possibility for collegiate students, or (c) myths and misconceptions associated with HIV infection and transmission. Comments falling into the first grouping are exemplified by Tom who said, "Right now it doesn't really affect me. I don't know anyone with AIDS—at least no one's said anything about it..." Aaron, however, summed up many students' attitudes towards HIV while demonstrating he may be the exception to the rule when he said, "It can't happen to me. Its never going to happen to anyone I know, so why should I worry about it? I mean, that's the mentality."

Kathy's comment that, "...[Case It! was] not *personally* personally [*sic*] [relevant], like 'cause I don't—at least I don't think I know—anybody with HIV or

AIDS…" is a good example the second group, personal denial. Her attitude is one that was repeated frequently where students acknowledged that HIV was in fact a problem, but not one that they would ever realistically have to deal with, as echoed by Greg when he said, "…it was kind of interesting to learn about where it [HIV] is now, but it really didn't have anything to do with me—has nothing to do with my future…" Some students however recognized the fallacy of this position, like Emma who said, "…I know we say that it's not relevant to us, but I mean, you could get it. You never know. You know, it could happen to us, and it's nice to know 'cause now we know more about it…"

The third grouping of comments referencing myths and misconceptions were less common than one might have expected; however, the majority of students in question (~63%) were senior biology majors who probably have had a greater exposure to information about HIV than the average citizen. The most common myth that was cited by students was that HIV is an African problem, and not really an issue in the industrialized world. This is evidenced by Jui-Fu's comment that, "I only know that there's a lot of AIDS cases in Africa…" and Lisa's statement that,

> I know that HIV is something that we should all be concerned about, and it is a world problem but, as far as being on my radar, it's probably one of the most minor things that I would think about…

Need-to-know science. Prior to conducting the focus group interviews, I expected a large number of students to make comments associated with Need-to-Know science, which is information or knowledge gained in response to specific or potential problems in a student's life. In fact, only 20 student comments were coded into the subcategory (1.7%; see Table 7). It surprised me that so many of the students interviewed contextualized their experiences as functional science, which applied to future vocational or professional need, rather than in terms of personal application as had been noted in a previous study. Comments coded here either referenced immediate applicability, or potential future need. Examples of the former include Zoë's statement that, "At first I wasn't real happy about doing it, but during the semester someone in my life has been diagnosed with HIV, so it's helped me understand the disease a lot," and Leah's acknowledgement that, "...[Case It!] just makes me more aware of what I should and shouldn't be doing." Ashley illustrated future relevance when she said, "...I also think it helps in personal life if it's your friend or loved one that's going to have to deal with this disease..." as does Teresa's comment that, "...if you did have to go get tested, you'd be one step ahead of the average person..."

Level of application. Many students at both the majors and introductory levels indicated that they felt Case It! had the potential to be a factor in helping students decide on biology or science as a major—especially if presented at lower level, such as high school and introductory courses. This perspective was illustrated by Kira, who said that,

> ...Potentially [this is the kind of experience that might lead people to be biology majors]. Maybe for like those Biology 150 classes that are just going through it right now... They're in their first or second year of college, so maybe it'd be more useful doing it at that stage...

Nicole said that the earlier students were exposed to projects like Case It! the better, saying, "If Case It! was brought to high school students, that would get them more interested in science, and maybe more interested in taking science as a major in college. Because that's what really got me interested in my major..."

Overview of case studies B-F

The next five case studies are class-specific investigations of the research questions. Included are case studies of all 5 classes tested at 4 study sites. Two classes at the University of Wisconsin–River Falls were tested, BIOL 150 an introductory biology course for majors, and BIOL 345 a majors level immunology course. BIOL 401 at North Carolina State A&T was a majors level molecular biology course, while MEDT 4531 at Interamerican University of Puerto Rico (Metropolitan Campus) was a majors and post-baccalaureate clinical immunology course, and BIOL 4600 at Interamerican University of Puerto Rico (San Germán Campus) was a majors level histology course.

Case study B: University of Wisconsin–River Falls, BIOL 150 (UWRF-NM)

Overview. Of the 50 students enrolled in BIOL 150 at the UWRF in spring semester 2009, 43 chose to participate in this study (86%). As Table 2 shows, participating students reflected the norms of the class in terms of class standing and gender. It is important to note that, although this is a major's level course, roughly 58% of all students were non-majors, primarily from the agricultural sciences. The 5 most popular career choices were agriculture, other fields, conservation, teaching, and veterinary medicine, and reveal this trend toward non-STEM fields.

Student performance. As Figure 5 shows, students at UWRF-NM significantly improved their performance from the pre- to post-test ($t(41)=4.265$, $p \leq .001$). As with the overall dataset, time was the only significant factor influencing performance. An item analysis of questions revealed that students significantly improved on only questions 1 and 6 (see Table 8). Again, ceiling effects may have limited results for question 2 as post-test means approach the maximum possible (M=3.381, max=4). Similar to overall results, participants at UWRF-NM significantly improved their confidence on all 6 test items, even when there was no statistical improvement in score (see Table 8).

Student intentions to persist. Students at UWRF-NM made more comments referencing persistence proxies than the overall average, accounting for a little more than 51% (n = 208) of all statements (see Table 9). Descriptive statistics indicate that while students generally agreed that Case It! reinforced their desires to be science majors (M=2.801, 1-5 Likert scale), they had slightly lower opinions than overall, cross-site average (M=3.304, 1-5 Likert scale). Nominally fewer students in this introductory class said the project was relevant to their lives (56%) compared to the cross-site mean of 59% for all students sampled, indicating a degree of universal relevancy. Of the 43 participating students from BIOL 150, 77% agreed that the Case It! project would help them with either future classes or careers, a full 10% lower than the cross-site average,

Table 8.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test at the University of Wisconsin–River Falls BIOL 150 (UWRF-NM)) non-majors level course (n = 42).

		Pts. poss.	Pre- mean	Post- mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.452	2.905	0.968	0.453**
Q2	Interpretation of Western Blot results	4	3.071	3.381	1.047	0.310
Q3	Comparison of ELISA vs. Western Blot	7	3.595	4.095	1.686	0.500
Q4	Application of results in counseling parents	4	1.667	1.905	1.165	0.238
Q5	Application of results in counseling about child	4	1.000	1.238	0.983	0.238
Q6	Interpretation of bioinformatics results	3	0.429	0.786	1.055	0.357*
		Pts. poss.	**Pre- mean**	**Post- mean**	**SD**	**Δ Confidence**
Q1	Interpretation of ELISA results	5	2.952	3.810	1.002	0.858**
Q2	Interpretation of Western Blot results	5	3.357	3.952	1.211	0.595**
Q3	Comparison of ELISA vs. Western Blot	5	2.429	3.452	0.924	1.023**
Q4	Application of results in counseling parents	5	2.952	3.905	1.168	0.953**
Q5	Application of results in counseling about child	5	3.073	3.585	1.227	0.512*
Q6	Interpretation of bioinformatics results	5	1.769	2.821	1.234	1.052**

Note: * Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$

Table 9.

Categories of comments and their instances for the University of Wisconsin–River Falls BIOL 150 (UWRF-NM) non-majors level course (n =405)

Category	*n*	*%*
Intentions to persist	**208**	**51.34%**
Instructional quality:	96	23.70%
Role-playing:	40	9.88%
Functional science:	35	8.64%
Self-efficacy:	29	7.16%
Community/Integrated into science:	8	1.98%
Beliefs:	**197**	**48.64%**
Learning:	42	10.37%
Diagnostic testing process:	39	9.63%
Science content:	37	9.14%
Communication:	23	5.68%
Multiple perspectives:	20	4.94%
Turned off science:	16	3.95%
Need-to-know:	11	2.72%
Stigma/Denial/Misconceptions:	9	2.22%

Note: Percentage calculated by [n(category) / total n]

but hardly surprising given the number of non-majors enrolled. When results were sub-divided by majors and non-majors groupings, the results were interesting, especially given that both non-majors and majors groups had roughly equivalent ratios of men-to-women (44:66 vs. 39:61) and freshmen-to-upperclassmen (28:72 vs. 22:78). Surprisingly, non-majors had slightly higher opinions of the project's future utility (79% vs. 75%) and relevance (60% vs. 50%) than majors. However, majors were more positive about the project's influence on their choice of major (M=3.000 vs. M=2.654).

As shown in Table 9, students from UWRF-NM made comments in all 5 persistence proxy categories found across all sites. Compared to overall averages, students in BIOL 150 equally valued instructional quality (23.7% vs. 21.6; see Tables 7 and 9) and feelings of community or integration (~2.0% vs. 1.8%; see Tables 7 and 9). Comments related to feelings of self-efficacy were more common at UWRF-NM (7.2%; see Table 9). The importance of role-playing and functional science was reversed at UWRF-NM. While still ranked 2 and 3 in number of comments, students in BIOL 150 made more comments related to role-playing (9.8% vs. 8.6%; see Tables 7 and 9) and fewer about functional science (8.6% vs. 10.0%; see Tables 7 and 9) than the overall average.

While only 42% of participants had declared science as a major, many said they thought Case It! would be useful in the future. Students like Noah and Logan spoke to the project's future application when they said that, "...[Case It!] definitely applies to my future career...and there are so many cases where…genetics, or nutrition…and diseases…come into play," and, "…I think Case It! really helped for my future classes…" Other students like Jessica were more direct about the influence of Case It! when she said, "…[it] helped me pick a major because it kind of helped me broaden my horizons as to what is out there for the science aspect of everything…" Jane said that, "…[because of Case It!] and what we've done…I [have] decided to go into genetic counseling."

Student beliefs. The vast majority of students at UWRF-NM agreed that the project was a good learning experience (93%) and 56% said it was relevant to their personal lives. As a group, students were confident in their knowledge of infectious diseases and genetic disorders (M=3.652, Likert scale 1-5). Students said that their interest in disorders had increased significantly as a result of participating in Case It! ($t(45)=5.197$, $p \leq 0.001$). Figure 8 shows that unlike the overall average, students in BIOL 150 thought the two most useful components of the project were conferencing and internet research. When the class was divided into majors and non-majors, the two groups disagreed on the projects value and relevancy, but the only significant difference was that non-majors had less confidence in their knowledge than majors students ($t(44)=2.388$, $p \leq 0.05$).

Students at UWRF-NM made fewer comments about their beliefs than the average (48.6% vs. 52.9%), but did comment on all 8 categories found overall (see Tables 7 and 9). The number of comments made within each category varied, with the majority falling into the learning (10.4%), diagnostic testing process (9.6%), and science content (9.1%) categories (see Table 9). Logan said, "…[I] like[d] the lab because you actually get to do it—the hands-on experience—and you know the kind of tests you need to do, and how to do them…" reflecting most students' ideas about learning. However, others reported one of the project's main benefits was developing analytical processes, like Nerissa who said that, "…Case It! helped me think a little bit more critically about the questions being asked of me…" Many of the student comments regarding diagnostic testing processes focused on the project's ability to demonstrate complex tests and procedures in a situation where it was okay to make mistakes, and where those mistakes were not costly in terms of either money or time. This belief was exemplified by Noah who said, "I felt like I learned a lot more, and it really made me understand how tests are run…" and Jane,

> …I like going on computers and knowing how to do it step by step because I think it would make me really nervous to just go in there [wet lab]. I'd probably do it [the test] and mess up. And then you've just wasted an hour of your time. But on a computer if you mess up you can just click "clear" and do it again, and you've only wasted like five minutes.

Many of the students at UWRF-NM expressed appreciation of the program's ability to connect content knowledge with application, which were coded as science content. Andrew spoke to me about how the real-world situations in Case It! helped prepare him, even though he's not a biology major saying,

> I'm in crop and soil science and I do a lot of sales and advising…and it's shocking what people don't know. So as far as a conferencing goes, [Case It!] does relate to real life experiences—how you would answer people—because I know these questions may be stupid, but believe me people to ask them. And they mean it.

Other students like Aaron were more general, as when he said, "…its pretty cool to learn all about the diseases," while Jessica said "…it's interesting to put all the different elements together and find out the results."

The remaining 5 categories of student beliefs were relatively similar to the overall findings, except for "turned off science" (~4.0% vs. 2.3%; see Tables 7 and 9). At UWRF-NM there were some students who were vocal in their dislike of the project because of its heavy reliance upon computer simulations. William said, "I felt removed from doing the actual scientific tests by just pointing and clicking on a file…" while Charlie said, "I'm just not good with computers at all…so it was just really, really [*sic*] confusing for me." Another student, Casey, said, "I'm a dairy science major, why do I need to know how to use computers?" Several students were exasperated at the lack of "wet lab" time, like Kira who said,

> …we had maybe two days that we actually spent in a live laboratory, and I feel like [for a biology class] it could have maybe hit home more if we had spent actual time in the lab as well as online.

Others like Megan said, "…I'm good with computers and everything, but honestly…I'm more of a hands-on person."

Level of application. While a few of the non-majors students (n = 7) at UWRF-NM said the Case It! project was too detailed and advanced, other students (both majors and non-majors) reported it was appropriate and beneficial. Jane said that Case It! "…caused a real spark—I really like genetics—it kind of has me rethinking my emphasis again. It was helpful, and I might change my major…" This sentiment was echoed by Jessica who said, "It…helped me pick a major because it kind of helped me broaden my horizons as to what is out there…" Other students like Jodi and Rebecca agreed that the project had positive effects on their future academic careers saying, "…it's another aspect of what I could be getting into as a major. I'm only a freshman, so I have time to change—maybe go a different way…" and "…it kind of has me thinking about going in a different direction with my [biology] major…"

Case study C: University of Wisconsin–River Falls, BIOL 345 (UWRF-M)

Overview. Roughly 97% (n = 39) of the students enrolled in BIOL 345 during spring semester 2009 agreed to participate in this study. Participants reflected the class averages in all ways with approximately a 25/75 split between juniors and seniors, and a 40/60 split between men and women (see Table 2). Students in this class were 95% biology majors. The five most popular career choices were other healthcare, research, other fields, medical technology, and biotechnology.

Student performance. Students' performance at UWRF-M significantly improved from the pre- to the post-test ($t(25)=2.599$, $p \leq 0.05$; see Figure 5). As with the aggregate dataset, gender did not influence performance, only time. An item analysis of questions revealed that students significantly improved on questions 3, 4, and 5, but significantly *decreased* on question 1 (see Table 10). This decrease only occurred at this site, and may have been the result of students' confusion between different tests or errors in interpreting the tests.

Table 10.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test at the University of Wisconsin–River Falls BIOL 345 (UWRF-M) majors level course (n = 27).

		Pts. poss.	Pre-mean	Post-mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.852	2.148	0.823	-0.704**
Q2	Interpretation of Western Blot results	4	3.444	3.370	1.035	-0.074
Q3	Comparison of ELISA vs. Western Blot	7	3.667	4.519	1.895	0.852*
Q4	Application of results in counseling parents	4	1.889	2.593	1.436	0.704*
Q5	Application of results in counseling about child	4	0.778	1.741	1.091	0.963**
Q6	Interpretation of bioinformatics results	3	1.308	1.692	1.061	0.384
		Pts. poss.	**Pre-mean**	**Post-mean**	**SD**	**Δ Confidence**
Q1	Interpretation of ELISA results	5	3.259	4.111	1.064	0.852**
Q2	Interpretation of Western Blot results	5	3.346	4.077	1.251	0.731**
Q3	Comparison of ELISA vs. Western Blot	5	2.889	3.708	1.076	0.819**
Q4	Application of results in counseling parents	5	3.037	3.926	1.281	0.889**
Q5	Application of results in counseling about child	5	2.885	3.885	1.020	1.000**
Q6	Interpretation of bioinformatics results	5	2.923	3.769	1.084	0.846**

Note: * Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$

Again, ceiling effects may have limited results for question 2 as both pre- and post-test means approach the maximum possible. Similar to overall results, participants at UWRF-M significantly improved their confidence on all 6 test items at $p \leq 0.01$ level, *even when they performed significantly worse* on a question or did not improve at all (see Table 10).

Student intentions to persist. The same themes and codes described in the previous section were applied to the focus group interviews and student surveys of pupils at UWRF-M. The overall picture presented was an intention to persevere in program. Comments related either directly to student persistence or persistence proxies accounted for just over 42% ($n = 216$) of all statements (see Table 11), roughly 5% fewer than the aggregate average (see Table 7). Students at UWRF-M had a slightly higher level of agreement that Case It! reinforced their desires to be science majors than the average (M=3.405 vs. M=3.304). Interestingly, more students in BIOL 345 (89% vs. 87% aggregate) thought Case It! would be valuable to them in future classes or careers, but 13% fewer felt that it was personally relevant to their lives (46% vs. 59%). Students like Sid said that, "...[Case It!] definitely reinforced my desire to go into bioinformatics," while others like Greg said, "...it's [the content knowledge] going to stick now. After the end of the semester, I'm still going to be able to remember this."

As Table 11 shows, student comments about persistence from UWRF-M reflect the same order as aggregate results, with slightly lower percentages.

Table 11.

Categories of comments and their instances for the University of Wisconsin–River Falls BIOL 345 (UWRF-M) majors level course (n =509)

Category	*n*	*%*
Intentions to persist	**216**	**42.44**
Instructional quality:	101	19.84
Functional science:	44	8.64
Role-playing:	41	8.06
Self-efficacy:	24	4.72
Community/Integrated into science:	6	1.12
Beliefs:	**293**	**57.56**
Diagnostic testing process:	74	14.54
Science content:	63	12.38
Learning:	59	11.59
Multiple perspectives:	34	6.68
Communication:	34	6.68
Stigma/Denial/Misconceptions:	15	2.95
Turned off science:	10	1.96
Need-to-know:	4	0.79

Note: Percentage calculated by [n(category) / total n]

Clearly the way material was presented in Case It! mattered to students, as the greatest number of comments at UWRF-M were about instructional quality (*n* = 101; see Table 11), and were more than double the next category, functional science (*n* = 44; see Table 11). Students reported that they appreciated the novel way in which Case It! introduced them to both material and procedures, and the speed at which they were able to conduct genetic tests. Maggie said, "...you see how [HIV] actually affects real people...And you see all sorts of different aspects, like they show you a little video," while Lisa said that, "...by reading the case studies, it made it more applicable to me...reading about people who actually... like this is their story, this is what happened to them... made it more real to me." Both Lisa and Olivia were positive about using the Case It! environment to conduct complex genetic assays when they said, "...doing [tests] on Case It!, it was giving us the results that it was supposed to be giving us," and "[With Case It!] you actually get results, whereas our lab went horribly wrong—we didn't get very good results on our Western Blots." Other students like Sid were more general in their praise stating, "I really liked it. I kind of felt like I was House curing people," referring to the popular television series.

Students at UWRF-M also appreciated the learning environment's ability to present them with "real-world" situations in which they could both apply theoretical knowledge and envision themselves in a professional context. Given that this was an upper division course populated primarily by seniors (see Table 2) who expect to be shortly on the job market, it is unsurprising that many students related this experience to needed occupational skills or translating theory to application. Comments related to these feelings were coded as either "functional science" or "role-playing" depending on the context, and aggregately accounted for approximately 16.7% of all student statements (see Table 11). Rachael wanted to be a nurse and said, "…I thought that [role-playing] gave me a lot more opportunity to…practice [compassion]—like being the counselor and stuff like that. So, I think that was probably the coolest part for me." This opportunity to practice professional skills was echoed by Maggie when she said, "…it was…really neat to do the [role-playing] portion of [Case It!]—we don't really get to do that a great deal in any other BIO courses, so that was also great." Autumn said, "I definitely think [Case It!] helped prepare me for a career," and Neil said that, "…it's like some practice if you will for future life, kind of a real-life situation."

Student beliefs. Roughly 92% of participants at UWRF-M thought that Case It! was a good learning experience for them, which was slightly lower than both UWRF-NM and the aggregate average, but not significantly so. It is interesting to note that only 46% of students said the project was relevant to their personal lives as compared to 56% with the introductory students at UWRF-NM and 59% of students overall. This may be linked to the relatively large number of comments made by students in this class related to stigma, denial, or misconceptions about HIV (n=15; see Table 11). Roughly 55.6% of all comments coded into this category were made by students at UWRF-M (see

Tables 7 and 11). Lisa's comment seemed to sum up many students' feelings about the project's relevancy,

> I know that HIV is something that we should all be concerned about, and it is a world problem, but as far as being on my radar, it's probably one of the most minor things that I would think about...

Aaron said flat out that HIV was not relevant to him, but amended that statement when he said, "I suppose if you include career in there, maybe...but personally it [HIV] isn't [relevant]." Other students like Katie chose to speak for the group with her denial of relevancy when she said,

> I think its hard for us to find it relevant to our lives, just because none of us are affected personally by AIDS or HIV. So, its hard for us to relate to this project because none of us have [it]...

A few students at UWRF-M like Emma did acknowledge that while HIV and AIDS might be relevant, there were social pressures to deny this saying,

> I know we say that its not relevant to us, but I mean, you could get it. You never know...It could happen to us, and its nice to know because now we know more about it so if someone we knew or we got it (God forbid!)...we know what to do.

Despite over half the class feeling that Case It! lacked personal relevance, participants at UWRF-M said the project increased their confidence in their knowledge of HIV (M=3.660), and increased their interest in HIV ($t(36)=5.097$, $p \leq 0.001$). Figure 8 shows students in BIOL 345 most valued the same two components of Case It! as the overall average, the virtual lab and conferencing. Pupils at UWRF-M made more comments about their beliefs (57.6%; see Table 11) than either the average (52.9%; see Table 7) or UWRF-NM (48.6%; see Table 9). While they made comments in all 8 categories, the majority of observations (~67%) were about diagnostic testing, science content, and learning (see Table 11).

Several students at UWRF-M found the Case It! project's ability to link disparate ideas in biology and science together (*n*=34), and its facilitation of communication techniques (*n*=34) especially useful (see Table 11). Noah said that Case It! helped him make connections because it, "…[puts you] in that perspective outside of learning the material, [where] you definitely have to learn what the people are going through." Ashley said that,

> [Case It!] kind of helped me think outside the box—it made me think of different things, different people are coming from different backgrounds, and classes that they've taken, so they ask different questions, and you're like, "Hey! Wait a minute...I didn't really think about that over there."

This idea was seconded by Greg when he said, "…it helped you think outside of how and what you would normally think." The opportunity to practice communicating with laymen appeared to be especially appreciated by those students expecting to pursue careers in the health sciences. Autumn said Case It! helped her by, "...being able to relate to your patients, and think on their level…I think sometimes people just get caught up thinking, 'Oh well this sounds more scientific…' but you have to think about what's going to be more understandable." This was echoed by both Eli and Catherine who said, "…you have to know how to…explain terms that people might not understand so that you can actually get your point across and tell them what they need to know," and "I definitely felt the most beneficial part was understanding the results, and being able to put them into words that a patient can understand." Tom was perhaps more practical when he said, "...you actually had to explain it, so you really had to know it."

Level of application. Several students at UWRF-M suggested that Case It! could significantly impact STEM program entrance and retention if offered at lower levels, such as high school and introductory courses. Kelly said that, "..if Case It! was brought to high school students, or intro classes, that would get them more interested in science," and Emma said that, "...this could definitely affect freshmen looking to pick a major." These comments echoed those of the beginning students in BIOL 150 at UWRF-NM described above. Overall, while most participants at UWRF-M said that the project had reinforced their desires to be science majors, they were already so invested in their majors in terms of time and money, almost nothing could convince them to switch.

Case study D: North Carolina State A&T University, BIOL 401 (NCA&T)

Overview. The class at NCA&T represented the greatest sampling deviance. Of the 20 students enrolled in BIOL 401, only 6 chose to participate in this study (30%), and all were women, whereas in the overall class 20% of students were men. Participants did however reflect the class averages for G.P.A. and class standing (see Table 2). The five most popular career choices were physician, other fields, research, teaching, and other health care.

Student performance. Unlike the previous two classes and the overall average, students at NCA&T did not demonstrate any significant performance improvement from the pre- to the post-test ($t(4)=1.500$; see Figure 5); however, this is likely due to the low number of participants that took both exams (*n* = 5) as gain scores for this class are slightly higher than those recorded for both UWRF-NM and UWRF-M (see Figure 6). An item analysis revealed that there was very little significant movement for students at NCA&T in terms of either question performance or question confidence (see Table 12). The only question to show significant improvement was item 5, and only question 1 showed a significant increase in confidence (see Table 12). Results from this class, however, must be carefully examined for two reasons: (a) ceiling effects definitely influenced results for question 2 as scores for both the pre- and post-tests were just 0.2 off the maximum possible, and probably influences confidence scores on questions 1, 2, and 4 as those means also approach the maximum value (see Table 12); and (b) the low number of participants reduces the probability that even a large difference would be statistically significant.

Student intentions to persist. A greater percentage of student comments from NCA&T referenced persistence proxies (54.2%; see Table 13) than the overall average (47.2%; see Table 7). All (100%) of the participating students agreed that Case It! would help them with future classes or careers, and they had a higher level of agreement that the project reinforced their desires to be science majors than the average (M=4.167). Students at NCA&T also said that the project was more relevant to their lives (66.7%) than the average (59%), UWRF-NM (56%), or UWRF-M (46%). Students like Leah said the project, "…helps you when you think about a career, and what you want to do," and Alice

Table 12.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test at North Carolina A&T BIOL 401 (NCA&T) majors level course (n =5).

		Pts. poss.	Pre-mean	Post-mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.600	3.600	1.000	1.000
Q2	Interpretation of Western Blot results	4	3.800	3.800	0.707	0.000
Q3	Comparison of ELISA vs. Western Blot	7	3.800	4.400	2.702	0.600
Q4	Application of results in counseling parents	4	2.400	1.600	0.837	-0.800
Q5	Application of results in counseling about child	4	1.000	2.200	0.447	1.200*
Q6	Interpretation of bioinformatics results	3	1.000	1.667	1.155	0.667
		Pts. poss.	**Pre-mean**	**Post-mean**	**SD**	**Δ Confidence**
Q1	Interpretation of ELISA results	5	3.800	4.800	0.707	1.000*
Q2	Interpretation of Western Blot results	5	4.400	4.800	0.548	0.400
Q3	Comparison of ELISA vs. Western Blot	5	3.000	4.200	1.095	1.200
Q4	Application of results in counseling parents	5	4.000	4.400	0.548	0.400
Q5	Application of results in counseling about child	5	3.800	4.200	0.548	0.400
Q6	Interpretation of bioinformatics results	5	2.000	3.333	0.577	1.333

Note: * Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$

Table 13.

Categories of comments and their instances for North Carolina A&T University BIOL 401 (NCA&T) majors level course (n =120)

Category	*n*	*%*
Intentions to persist	**64**	**53.33**
Instructional quality:	27	22.50
Role-playing:	18	15.00
Functional science:	11	9.17
Self-efficacy:	5	4.17
Community/Integrated into science:	5	4.17
Beliefs:	**54**	**45.00**
Diagnostic testing process:	20	16.67
Communication:	9	7.50
Science content:	8	6.67
Learning:	8	6.67
Multiple perspectives:	3	2.50
Need-to-know:	3	2.50
Stigma/Denial/Misconceptions:	2	1.67
Turned off science:	1	0.83

Note: Percentage calculated by [n(category) / total n]

said, "...it's given me more experience than I would have gotten with my other classes, and it helped reinforce why I want to go to medical school."

As Table 13 shows, students at NCA&T valued the overall instructional quality of the project roughly equally to the average (see Table 7), but placed a greater importance on role-playing (15.0%). Students said that role-playing afforded them numerous experiences they had not had access to previously in their education, such as the chance to act as a teacher, to practice asking and answering questions in a real-world environment, and the opportunity to act as professionals conferencing with peers. Winnie said, "...the role-playing was fun for me...it was good to just sit down and think about it and ask more questions." Alice said the, "...conferencing was very important because [the other students] asked me questions that I hadn't even thought about...so that helped me learn about different—other—aspects of HIV that I wouldn't have looked into before then." She followed up by saying that she, "...had to go back and get extra information from [other resources] because the questions that I got asked—well, they probably weren't in the textbook." Teresa spoke to the idea of bi-directional learning as a product of role-playing when she said,

> You're both learning from each other because one of us is role-playing as one person, and the other one is role-playing as the other, so you were supposed to be a doctor and a family member and you would be equally learning the same from each other.

This perspective was backed up by Kathy, who liked the role-playing aspect of Case It! because, "...its like I'm learning from them [the 'patients'] and they're learning from me."

Some students ($n = 5$; see Table 13) at NCA&T liked that the project made them feel like they were an active member of, or professionally integrated into, the scientific community. While not accounting for a large percentage of comments, students in BIOL 401 did mention it more than twice as often (4.2%; see Table 13) as the overall average (~2.0%; see Table 7). These statements are important because they indicate that the Case It! project has the potential to help students transition from thinking of themselves as passive learners to active and capable agents of inquiry. Tanisha said that, "...[Case It!] made it more like you were actually a doctor," and "I think the cases linked to [the virtual labs] made you feel like you were actually working with somebody—doing someone good." Leah spoke about bridging the gap between her social and professional communities when she said, "...HIV affects African-American females the most now I believe in our age group, so [Case It!] really made me feel like I could do something to help. You know, make a difference." Alice's commented simply that, "...it felt good to think of myself as a doctor."

Student beliefs. All (100%) of participants at NCA&T thought that Case It! was a good learning experience for them, which was slightly higher than the aggregate average of 95%. The majority of students (67%) found the project to be relevant to their lives, and as a group NCA&T students were very confident in their knowledge of HIV (M=4.500). Participants also reported a significant increase in interest from before to after Case It! ($t(5)=3.953$, $p \leq 0.05$). Figure 8 shows that students at NCA&T agreed with the overall average that the virtual lab was the most important and useful component of Case It!; however, they said the next most useful aspect was creating online webposters. They made fewer comments about their beliefs (45%; see Table 13) than the aggregate average (52.9%; see Table 7) or students at UWRF-NM (48.6%; see Table 9) or UWRF-M (57.6%; see Table 11). Of the 54 comments made about beliefs, over 83% were in four categories (a) diagnostic testing; (b) communication; (c) science content; and (d) learning.

As with both UWRF-NM and UWRF-M, students at NCA&T liked the fact that Case It! allowed them to quickly and accurately conduct complex genetic tests without the huge investment of time that a wet lab would require. Several students noted that because of the speed at which Case It! runs tests, mistakes were learning experiences rather than frustrating wastes of time. This perspective is typified by Tanisha who said,

> ...I liked the lab because...in the lab [Case It!], plenty of times I messed up on the loading [DNA samples] part, but in the lab [wet lab] if you do that, its going to be hours before you can redo the test.

Alice immediately followed with the comment that one could, "...just press 'clear'..." and start again without hours of prep work. Other students appreciated the range of tests and information available, like Leah who said, "...I thought it was interesting that we could use the bioinformatics [tools] and show who you [*sic*] got the disease from, *and* who that person actually got the disease from." Tanisha liked that she could engage in discovery learning telling me that, "...I didn't know that you can actually track [viral loads], like over months, and see how the virus has increased." Alice thought, "...[Case It!] was a good simulation of actually using infectious diseases, because we'd probably never be able to work with these sorts of infectious diseases otherwise."

A number of comments referenced specific science content that the project helped students learn (*n* = 8; see Table 13). Some students liked that Case It! allowed them to practice running and reading several types of genetic tests, such as Teresa who said, "...sometimes interpreting tests is hard, but [Case It!] makes it easy," and Tanisha who said, "...it allows you to see the process that someone actually goes through to get the results." Other students like Kathy enjoyed the fact that the project was not formulaic with locked in results stating, "I thought it was cool that you could get a false positive with [Case It!] just like in real life..." Transmission and treatment of HIV were the subject of other comments. Leah said, "...it was interesting to know that just because some of the cases were in the U.S. and some were in Africa, they all contracted [HIV] the same way." Teresa said, "...it was interesting to see how long it takes for the medicines to start working against the virus."

A few students (*n* = 3; see Table 13) at NCA&T related the information they were learning either to current or potential personal use in the category "need-to-know science." Leah said that,

> [Case It!] informed me more, and it is going to make me be more careful that I was being before because of all the different cases and the different background of each person, and how they actually contracted the virus. It just made me more aware of what I should and shouldn't be doing.

Teresa talked about more specific application of her knowledge when she said, "...if you did have to get tested, you'd be one step ahead of the average person," while Winnie simply said, "...you could get it. You just never know, so I'm glad I did [Case It!]."

Level of application. As with UWRF-M, students at NCA&T reported that the project did reinforce their desires to be scientists, but that they were unlikely to have switched programs because they were so heavily invested. They did think though that Case It! had the potential to positively influence entrance and retention of students into STEM fields if offered earlier.

Case study E: Interamerican University of Puerto Rico, Metropolitan Campus, MEDT 4531 (IUPR-M)

Overview. Only 23% (n = 6) of the students enrolled in MEDT 4531 agreed to be part of this study. Participation was affected by the timing of testing and interviews, which had to be scheduled after 4:30pm on a day when students had taken a final exam for another course. As Table 2 shows, study participants closely mirrored overall averages for their class in every way except for the ratio of men to women. Men and women were equally represented in the focus group interviews, but men accounted for only about 17% of the overall class. All students in MEDT 4531 were either seniors or post-baccalaureate. The five most popular career choices for IUPR-M were medical technology, other healthcare, research, biotechnology, and physician.

Student performance. Like NCA&T, students at IUPR-M did not demonstrate any significant performance improvement from the pre- to the post-test (t(4)=1.677; see Figure 5); however, this is again likely due to the low number of participants who took both the pre- and post-tests (*n* = 5). Figure 6 shows that students at IUPR-M in fact posted the largest gain scores for all five classes tested, but not significantly so. An item analysis of questions showed that there was significant improvement only on question 4 (see Table 14). Just like every other previous site and the overall average, it appears that ceiling effects may have influenced gain scores on question 2 where both pre- and post-test scores approach the maximum value. Student confidence in their answers at IUPR-M improved significantly on questions 1-4 at the $p \leq 0.05$ level or better (see Table 14), which is similar to both the overall averages, and results from UWRF-NM and UWRF-M. As with results from NCA&T, the small sample size requires that all results be carefully assessed.

Student intentions to persist. Participants at IUPR-M only mentioned four of the five categories identified as persistence proxies, with roughly 61.5% of all their comments falling into these groupings (see Table 15). As with the other sites, student comments from IUPR-M present the impression of intending to persist. As with NCA&T, all of the students at IUPR-M agreed that the Case It! project would help them with future classes and careers. These students also had a higher opinion that the project reinforced their desires to be science majors than the overall average (M=4.000 vs. M=3.304). Unlike all other sites, all

Table 14.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test at Interamerican University of Puerto Rico–Metropolitan MEDT 4531 (IUPR-M) majors level course (n = 6).

		Pts. poss.	Pre-mean	Post-mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.167	2.333	0.753	0.166
Q2	Interpretation of Western Blot results	4	3.500	3.667	1.169	0.167
Q3	Comparison of ELISA vs. Western Blot	7	4.000	4.000	1.414	0.000
Q4	Application of results in counseling parents	4	1.167	2.333	0.753	1.166*
Q5	Application of results in counseling about child	4	0.833	1.500	1.506	0.667
Q6	Interpretation of bioinformatics results	3	0.600	1.800	1.095	1.200
		Pts. poss.	Pre-mean	Post-mean	SD	Δ Confidence
Q1	Interpretation of ELISA results	5	3.000	4.400	0.548	1.400**
Q2	Interpretation of Western Blot results	5	3.500	4.667	0.753	1.167*
Q3	Comparison of ELISA vs. Western Blot	5	3.333	4.000	0.516	0.667*
Q4	Application of results in counseling parents	5	3.500	4.500	0.632	1.000*
Q5	Application of results in counseling about child	5	3.167	4.333	1.472	1.166
Q6	Interpretation of bioinformatics results	5	2.600	4.200	2.302	1.600

Note: * Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$

Table 15.

Categories of comments and their instances for the InterAmerican University of Puerto Rico-Metropolitan MEDT 4531 (IUPR-M) majors level course (n =39)

Category	*n*	%
Intentions to persist	**24**	**61.54**
Instructional quality:	13	33.33
Functional science:	8	20.51
Community/Integrated into science:	2	5.13
Self-efficacy:	1	2.56
Beliefs:	**15**	**38.46**
Learning:	8	20.51
Diagnostic testing process:	5	12.82
Need-to-know:	1	2.56
Communication:	1	2.56

Note: Percentage calculated by [n(category) / total n]

participants (100%) found the learning experience to be relevant to their lives. Students like José said, "...you can really relate what's happening in Case It! to real life and with what you are going to do in your job." Tanira said that, "We've had a really good experience with [Case It!]," and Caesar said that, "It really helps you visualize what you need to do."

Participants spoke about persistence proxies far more often than previous sites or the aggregate average (see Table 7 and 15); however, the vast majority (87.5%) of these comments were either about instructional quality ($n = 13$) or functional science ($n = 8$; see Table 15). Most of the students I spoke with at IUPR-M appreciated that the project provided them with real-world situations, like Tanira who reported that she said personally engaged because, "It was real cases of real people." Caesar said it had gotten him excited to learn because, "...it got me thinking so much!" and because he, "...liked the HIV cases and found the topic interesting."

Other students liked that they were able to apply knowledge they gained in Case It! directly to their future careers. José said, "...now we have the basic knowledge of what we will do in our jobs." Caesar liked Case It! because, "It lets you see what is happening, and it makes you feel like you are a doctor." Margerie liked the level of fidelity between the virtual environment and wet labs, telling me, "It's the same in the lab as in the program...You get to know what you have to do—you get to see it." This sentiment was echoed by Daniel when he said,

"…we understand because we're practicing what we've learned. So, it's very helpful."

Student beliefs. All (100%) of participants at IUPR-M thought that Case It! was a good learning experience, and that it was relevant to their lives. These are the highest levels of agreement recorded for the study. Only NCA&T and IUPR-SG shared such high opinions of the project being a good learning experience. IUPR-M was the only site where *all* students reported the project was relevant to their personal lives. Students here were also very confident in their knowledge of HIV (M=4.167, Likert scale 1-5). Students said they significantly increased their interest in HIV from before to after the Case It! experience ($t(5)=4.472$, $p \leq 0.01$), and found the virtual lab and biotechnology to be the most valuable components (see Figure 8).

Only 38.5% ($n = 15$) of all student comments from IUPR-M were related to beliefs about Case It! (see Table 15). Of these, the vast majority ($n = 13$, 86.7%; see Table 15) were about either learning or diagnostic testing processes. Daniel spoke about the learning opportunities Case It! affords when he said, "You got to apply the theory—it was like a hands-on training [*sic*]. A lot of understanding, not just reading and reading," and "…with Case It! we got to practice [lab techniques]." José went on to explain that, "Our culture, we're more visual. We learn more when we see things, and that is one way that [Case It!] helps. You can learn." Omyra said that, "[Case It!] helps you apply knowledge from books, and that'll stick with me longer."

Tanira talked about how much she liked the virtual lab saying, "I enjoyed how easy it was to learn it, how fast and easy it was. I liked that you could see the whole process too." Omyra thought the bioinformatics portion of the project was the best aspect for her saying, "I enjoyed learning the genetic [history] of the virus HIV." She went on to tell me that, "[Case It!] helps me to understand the process and how it goes on. And the function of each test, and the results of that test." José liked that he could, "...choose how to do a test, and how you interpret the results."

Level of application. There were no student comments from IUPR-M related to at what level Case It! should be applied.

Case study F: Interamerican University of Puerto Rico, San Germán Campus, BIOL 4600 (IUPR-SG)

Overview. Approximately 55% (*n* = 12) of the students enrolled in BIOL 4600 during spring semester 2009 agreed to participate in this study. As Table 2 shows, participants reflected the class averages in all ways with 3 exceptions: (a) participant GPA was slightly higher than average; (b) participant age is slighter lower; and (c) no juniors or post-baccalaureate students enrolled chose to participate. All students taking BIOL 4600 were biology majors. The most popular career choices for participants were physician and other health care fields.

Student performance. As with NCA&T and IUPR-M, students at IUPR-SG did not demonstrate any significant performance improvement from pre- to post-test (t(10)=1.576; see Figure 5), although scores did increase. Figure 6 shows that IUPR-SG reported the lowest gain score; however, none of the gain scores shown are statistically different. Therefore, it is possible that low participation numbers again influenced the results, as with IUPR-M and NCA&T. An item analysis of questions showed that there was significant improvement only on question 6 (see Table 16). It is interesting to note though that unlike all other study sites, there is no evidence of ceiling effect limiting results for question 2 (see Table 16). The only significant increase in confidence reported by students at IUPR-SG was on question 1. While the number of participants (*n* = 12) at this site is larger than either NCA&T or IUPR-M, it is still likely that there are not enough data points to convey statistical importance. Given that none of the gain scores from the five sites tested are statistically different, and that both UWRF-NM and UWRF-M recorded significant increases in performance from pre- to post-test, a logical extrapolation of results suggests a larger sample size at NCA&T, IUPR-M, and IUPR-SG might yield significant gains.

Student intentions to persist. Comments related either directly to student persistence or persistence proxies accounted for just over 40% (*n* = 35) of all statements (see Table 17), roughly 7% fewer than the aggregate average (see Table 7). Students at IUPR-SG were the most positive that Case It! reinforced their desires to be science majors (M=4.333). The vast majority of students (92%) at IUPR-SG reported the project was relevant to their lives, and all (100%) agreed that it would help them with future classes or careers.

Table 16.

Changes in mean student performance and confidence on learning assessment test from pre- to post-test at Interamerican University of Puerto Rico–San Germán BIOL 4600 (IUPR-SG) majors level course (n = 12).

		Pts. poss.	Pre-mean	Post-mean	SD	Δ Mean
Q1	Interpretation of ELISA results	4	2.500	2.750	1.055	0.250
Q2	Interpretation of Western Blot results	4	3.250	3.083	1.115	-0.167
Q3	Comparison of ELISA vs. Western Blot	7	2.667	3.500	1.899	0.833
Q4	Application of results in counseling parents	4	1.272	1.364	1.446	0.092
Q5	Application of results in counseling about child	4	0.727	0.818	1.044	0.091
Q6	Interpretation of bioinformatics results	3	0.500	1.167	0.985	0.667*
		Pts. poss.	**Pre-mean**	**Post-mean**	**SD**	**Δ Confidence**
Q1	Interpretation of ELISA results	5	2.500	4.167	1.557	1.667**
Q2	Interpretation of Western Blot results	5	3.546	4.272	1.737	0.726
Q3	Comparison of ELISA vs. Western Blot	5	2.500	3.500	1.491	1.000
Q4	Application of results in counseling parents	5	3.400	4.300	1.524	0.900
Q5	Application of results in counseling about child	5	3.400	4.300	1.524	0.900
Q6	Interpretation of bioinformatics results	5	3.167	3.167	0.894	0.000

Note: * Significant at $p \le 0.05$
** Significant at $p \le 0.01$

Table 17.

Categories of comments and their instances for InterAmerican University of Puerto Rico–San Germán BIOL 4600 (IUPR-SG) majors level course (n =87)

Category	*n*	%
Intentions to persist	**35**	**40.23**
Functional science:	18	20.69
Instructional quality:	14	16.09
Community/Integrated into science:	2	2.30
Self-efficacy:	1	1.15
Beliefs:	**52**	**59.77**
Diagnostic testing process:	22	25.29
Learning:	15	17.24
Science content:	8	9.20
Multiple perspectives:	3	3.45
Communication:	3	3.45
Need-to-know:	1	1.15

Note: Percentage calculated by [n(category) / total n]

Of the 35 comments made by students about persistence proxies, 91.4% referred to either functional science or instructional quality (see Table 17). Many of the students at IUPR-SG linked what they were learning in Case It! to future jobs or careers, like Carla who said, "I want to be a doctor in the future, and I understand from the program that I have to examine each case as carefully and as thoroughly as doctors really must." Eva expressed this same perspective when she said, "I got the experience of being the doctor, and doing the tests, and giving the patient the results." Miguel said,

> Its important to learn about different areas, even though you're going to be a professional, so if something else happens, or a different case, or if someone else comes in with a different illness that's not common, you will know [what to do].

Ferdinand and Tanya were more general in their comments, "...my knowledge built from Case It! [will] help me in a future job," and "...the hands-on training...is going to be helpful in the future."

Students at IUPR-SG appear to have especially appreciated the autonomous learning functions of the Case It! project, Myra said, "I liked that I could get a certain disease, and know the results afterward by myself," and Juan said, "I liked it because in this college, we don't have that many opportunities to do research, and I don't have to leave my desk to do my research." Other students particularly said the project served as a mental springboard for them to satisfy their curiosities about other diseases and disorders. Jorge exemplified this attitude when he said,

> It increased my curiosity for other diseases that are not found in Puerto Rico, but are in other parts of the world. I know now the diseases and the tests, and if you put [an unknown] disease in front of me, I am more able to figure it out, even though I'm not from those places. And I know how to [deal with] the diseases [when they] come up.

Maritza echoed this idea stating, "I can learn about diseases that I have never seen or never heard about. Now I can understand more about them because of the program." Still other students just enjoyed the novelty of an alternate instructional approach, like Stephan who said, "I enjoyed the virtual lab, even though we used normal methods in the laboratory, this is different—out-of-the-box—and I enjoyed working with them. It was very interesting for me."

Feeling personally or emotionally involved with the characters of the cases was a common sentiment across all sites, but was especially noticeable amongst students in BIOL 4600. Students like Luisa said,

> I felt emotionally involved with the case of Jennifer. Actually the case Jennifer is close to my age, and as typical young adults—we are careless sometimes, and we do things that we should probably not be doing, but we still do them—and the case opened my eyes to be more careful about what I do in my life.

Maritza said, "It really opened my eyes," and Cruz said, "...it helped to research just one specific case study...to see how [HIV] affects people on this sort of level—just to get a personal aspect."

Student beliefs. All (100%) of the participants from IUPR-SG thought Case It! provided them with a good learning environment, and 92% agreed that it was relevant to their personal lives. Interestingly, even though only question 1 demonstrated any significant increase in confidence (see Table 16), students at

IUPR-SG were the most confident in their knowledge of HIV (M=4.333) of all the sites. Students also reported that the project significantly helped them increase their interest in HIV ($t(11)=7.091$, $p \leq 0.001$). Unlike at other sites tested, Figure 8 shows that students at IUPR-SG liked the internet research component of Case It! the best, followed by both the virtual lab and biotechnology tools.

Almost 60% of all student comments from IUPR-SG were coded as pertaining to student beliefs (see Table 17). Different from the overall results, no student comments were coded as either "turned off science" or "stigma/denial/misconceptions" (see Tables 7 and 17). The two most common categories were diagnostic testing procedures and learning. Students like Myra said they particularly liked the bioinformatics portion of Case It!, "…because in every aspect [of biology] today, we use technology, internet, and labs, and it is going to be very useful for me." Other students like Carla appreciated the virtual lab because, "…I could use a lot of techniques and I could see the difference in results in the virtual lab." Another perspective was expressed by Cruz who said, "I enjoyed [the virtual lab] because I don't need the human part—where we could like, ruin it, or break it, or not get the test result as they are supposed to come out." Still others focused on the virtual lab's ability to inform treatment, like Kira who said,

> It is good to know the way the treatment is going to go, or the sequence of the tests, for when I start working, or the statistics of how long a person may live with that condition, or how long they are going to work with me, or medicines and all types of treatments.

Miguel was more general in his praise when he said, "I liked it because I now know what each test is, and how to interpret the results."

Many of the students at IUPR-SG said they appreciated the different learning opportunities Case It! afforded them, like Jorge who said, "...now I can apply [bioinformatics] research to the knowledge for myself [*sic*]" or Camilla who said, "...it was a real hands-on experience that we could learn from." Others like José said, "For me it was a very good experience. It helped me with my knowledge and basis in biology." Myra expanded her learning beyond physiology saying, "...even though HIV affects the immunology of the body, I could see how it affects the feelings and psychology as well," and, "This project helped me, and it would help other people build their knowledge—it can help normal people understand diseases."

Level of application. There were no student comments from IUPR-SG regarding at what level Case It! should be applied.

CHAPTER 5: Discussion

In this section I will first summarize the instructional efficacy of the Case It! learning environment, itemizing 5 key pedagogical components. Second, I will illustrate some interesting site differences worth noting. Innovations that make the Case It! project unique in undergraduate STEM reform will be presented third. Fourth, I will describe how the project motivates students to learn, and fifth, describe some limitations of the study. Sixth, I will present ideas for future research. Seventh, key implications for instructors, future instructors, and agencies will be described. Finally, I will present my conclusions.

Overall, the Case It! learning environment appears to be an effective pedagogical tool in stimulating student engagement, interest, and intentions to persist in their declared major. Students overwhelmingly told me in focus group interviews that the project was a good learning experience, fun, engaging, empathetic, and reinforced their intentions to be science majors. The multimedia, case-based learning environment created an overall context for material from multiple classes that allowed students to fit all the pieces of their previous academic instruction together into a single, comprehensive picture—and to place themselves within that picture. These findings were in sync with previous research that demonstrated both case studies and multimedia learning environments may aid students by developing analytical reflection processes (Callahan, et al., 2008; Dori, et al., 2003; Lundeberg, et al., 1999; R. A. Smith & Murphy, 1998), the ability to interact with material via multiple avenues of thought

(Herreid, 2006; Kumar & Sherwood, 2007; Wolter, Lundeberg, et al., 2009), and by creating linkages between superficially disparate content areas (Bergland, et al., 2006; Rybarczyk, et al., 2007; Wolter, Lundeberg, et al., 2009).

Specifically, five aspects of the Case It! program may be singled out as especially effective pedagogically by both the literature and student comments.

1. It offers *dynamic, high quality* instruction that is well received and reviewed by students. Over 26% of all student comments were related to instructional quality, and the vast majority of these were positive. Students enjoyed the autonomy and personal connections that using case studies and multimedia content offered.
2. Case It! actively engages students in their own learning, creating deep links to content. Participants noted role-playing, peer conferencing, and developing a personal relationship with the content and case as especially effective tools for engagement and motivation (Wolter, Lundeberg, et al., 2009).
3. Engaged students are more likely to be retained because material is more relevant and enduring, and they are able to translate theoretical knowledge in application scenarios. This in turn leads to perceptions of self-efficacy and the ability to envision themselves as science practitioners, both of which are proven effective pedagogical tools (Astin & Astin, 1993; Rybarczyk, et al., 2007; Savery, 2006; Seymour &

Hewitt, 1997; Tobias, 1990). Case It! is very effective in helping students imagine themselves as scientists.

4. Case It! provides students with practical, real-world experience with content and lab processes. It also exposes them to the humanistic side of science, which is uncommon, demonstrating the *effect* of their work. Focus group interview comments indicate that students were both enthusiastic and surprised by this. The traditional science lecture is typically very analytical and factual, rarely illustrating connections between science and society (Aikenhead, 2007), so many students found the project's ability to do so illuminating.
5. The project stimulates student curiosity and interest. Many participants expressed a desire to know more than what instruction provided, and many are driven to conduct independent research to answer their own questions. These questions were not just about content, but also included such topics as advanced lab procedures, empathetic and interpersonal connections, and the application of their knowledge in diverse situations. All of these scenarios created a unique and enduring bond between the material, the experience, and the student that can potentially increase retention.

Site differences

Individual class analysis identified differences between and within sites. For example, underclassmen at UWRF found more validity and relevance in the project by projecting its potential use to them *personally* while upperclassmen from all other classes predominantly viewed it as a *professional* resource. The introductory biology course at UWRF provided an interesting contrast to the upper division courses, especially in comparing opinions between non-majors and majors. One might expect non-majors to have a lower overall opinion of a project that required such deep analysis and aggregation of knowledge; however, this was not borne by the data. Even though Case It! is a involved project that deals in depth with complex ideas, this study has shown that it is equally applicable and effective at both the introductory and upper division levels. This is probably a result of the scalable nature of learning within Case It! where students can be engaged at multiple levels and autonomously direct their own learning.

Another interesting difference identified between sites was the stark contrast in socio-cultural stigma or denial associated with HIV/AIDS in both classes at UWRF versus the other 3 sites. Over 92% of the student comments coded as stigma, denial, or misconceptions about HIV came from students enrolled at UWRF; however, students at IUPR-M and IUPR-SG did not once mention stigma related issues. Whereas students in Puerto Rico and at NCA&T noted they were in some of the highest risk categories for contracting HIV, many students at UWRF were adamant that the disease was irrelevant to them because they thought they could never get it.

Overall, students in Puerto Rico appeared more positive and enthusiastic about Case It! than those from either UWRF or NCA&T, although 95% of all students found the project to be a good learning experience. Puerto Rican students also emphasized the flexibility that the learning environment offered them in terms of the number of disorders they could potentially study, and the costs of doing so. In this respect they took perhaps a more practical view of the project's application and potential than students at other sites who appreciated the experience but also wanted more wet labs.

Instructional innovation

An effective pedagogy. Student participants in this study identified the unique and high quality of instruction as a successful component of the Case It! learning environment. Learning climate clearly affects students' intentions to persist in program (Tobias, 1990; Wright, Sunal, & Bland Day, 2004). Seymour and Hewitt (1997) found that perceptions of environment, such as poor teaching and being turned off science by bad experiences, are important influences on students' decisions to leave STEM fields. O'Neal, Wright, Cook, Perorazio, and Purkiss (2007) found that both instructor and student engagement, interest, and interaction can have a positive effect on student persistence in STEM programs, and research by other scholars substantiate these finding (e.g. Astin & Astin, 1993; Bonous-Hammarth, 2000; Felder, 1995; Tobias, 1990). Studies investigating how instruction impacts retention have found that sympathetic, student-centered learning environments are positive proxies of student persistence in program (Bonous-Hammarth, 2000; Grandy, 1998).

Tinto (1993) states that one of the most important ways to reduced student attrition in general is to generate social integration among students. Previous studies focused primarily on student-to-student or student-to-faculty connections (e.g. Baird, 2000; Braxton & Lien, 2000; Stage & Hossler, 2000; Tinto, 2000; Tinto, 2007); however, emerging research has also demonstrated the importance of student-to-content connections (Wolter, Kang, Lundeberg, Herreid, et al., 2009; Wolter, Lundeberg, et al., 2009). These studies along with others (e.g. Savery, 2006) have demonstrated that case-based instruction has the potential to create personal connections between students and the material. Wolter, Lundeberg, and Bergland (2009) found that content mattered to students and had the potential to both motivate and engage students. Projects like Case It! can stimulate student integration with the material by engaging on multiple academic, personal, and emotional levels.

One of the project aspects on which students commented most frequently was that it cultivated links between the material and their lives—a development that students said they appreciated. Case It! personalized content and made it "more real" to students, and because of this many believed they would retain the information longer. It also inspired many students to learn more than required because they wanted to, "...find out for those people..." and they felt emotionally involved. Research has shown that when students feel personally engaged in their own instruction and have a tangible connection with material, they are less likely to drop out of program (Seymour & Hewitt, 1997; Tobias, 1990).

The creation of active engagement learning environments in STEM classes has been proven to improve student performance (Callahan, et al., 2008; Felder, 1995) and can increase student interest (Herreid, 2006; Prince & Felder, 2006; Wolter, Lundeberg, et al., 2009). A previous study of the Case It! learning environment found that it engages students on multiple academic, personal, and emotional levels, and can create perceptions of relevancy (Wolter, Lundeberg, et al., 2009). Koballa and Glynn (2007) state that, "Science learning experiences that are fun and personally fulfilling are likely to foster positive attitudes and heightened motivation toward science learning and lead to improved achievement" (p. 94). Participants repeatedly reported across study sites that Case It! was both fun and interesting, so the project appears to have accomplished this goal. Because students were having fun with in the learning environment, they not only significantly increased their topic interest, but also their desire to learn. Actively engaging students in material caused them to take a more dynamic role in their own education. This is borne out by the fact that several students chose to conduct autonomous, additional research on their case because it had piqued their interest, stimulated their curiosity, or involved them in such a way that they felt it incumbent upon themselves to dig deeper to find answers. Engaged students are more likely to persist in program because they feel like active participants in their own education, feel incorporated into the community of scholars in the sciences, and develop perceptions of self-efficacy

Aikenhead (2006) noted that personal curiosity was one of the most significant driving factors for students in science education. This study and others have shown that Case It! project is extremely good at piquing students curiosity, empathy, and engagement (Bergland, et al., 2006; Wolter, Lundeberg, et al., 2009). The personal connection that students develop with individuals in the cases frequently drives them to delve deeper into the project than is required. Responding to this stimulus, students conducted autonomous research either to answer questions that other students asked of them in peer conferencing, because they felt a sense of responsibility to the patients, or simply because they wanted to know more.

Students cited role-playing and peer conferencing as two of the most engaging components of Case It! Role-playing can increase student engagement, allowing students to be more active in developing their own topic interests (Kofoed, 2006), and can making science more meaningful to students (Cronin-Jones, 2000). It can also help students understand how classroom knowledge translates into "real-world" knowledge useful to them in their daily lives (Kalumuck & Doss, 2004). By immersing students in a contextualized environment, the addition of role-playing can aid in understanding concepts that might otherwise be abstract and difficult to comprehend (Hokanson, et al., 2008). By situating the role-playing in the context of real cases, affecting real individuals, this project helped students apply the relatively abstract facts and information they learned in the classroom in authentic and tangible scenarios.

The use of role-playing in Case It! not only allowed students to view issues from multiple perspectives, but also provided an alternate dimension to the learning environment that allows students to learn in safe and non-judged interaction with the professor and other students (Kang & Lundeberg, 2008; Wolter, Lundeberg, et al., 2009). Research from Europe suggests that these informal learning contexts can also reduce student performance anxiety and subsequently increase desire to participate (Gläser-Zikuda, Fuß, Laukenmann, Metz, & Randler, 2005). Previous research on role-playing within the Case It! environment demonstrated that students respond positively to its inclusion, and frequently become so involved in the role-play that they "lose themselves" in the context (Wolter, Lundeberg, et al., 2009). In the same study, students said they liked the ability to take on the persona of an scientist, to "be the expert" (Wolter, Lundeberg, et al., 2009). Kang and Lundeberg (2008) followed selected students in Case It! through all of their conferencing for a semester, and found that participation in role-playing led to a development of both student identity and a deeper understanding of the subject.

Discussion generated within cases or via role-playing interactions was pedagogically useful because it can trigger cognitive conflict and lead students to critically analyze topics in an effort to resolve the conflict (Levin, 1999). It was interesting to note that opinion was divided on the utility of role-playing and conferencing, especially amongst upperclassmen. Some students, especially women, appreciated the opportunity to help laymen understand science via role-playing, whereas a few (especially men) found validity only in conferencing as peers.

A scalable pedagogy. Results from this study show that unlike a preponderance of other pedagogical tools used in undergraduate STEM reform (e.g. Fairweather, 2008; P. Fisher, et al., 2005), successful implementation of the Case It! learning environment *is not instructor dependent.* The program is effective regardless of who is teaching it, where it is taught, in what language it is taught, and to whom it is taught. Even though the performance data collected in this study was potentially influenced by multiple distracting factors like: (a) teacher, (b) length of instruction, (c) time-on-task, (d) site, (e) language variation, and (f) specific content beyond the cases used; all students, across all sites demonstrated a significant increase in pre-/post-test gain score.

In the realm of undergraduate STEM education reform, this finding is important because even though there are a host of studies demonstrating the efficacy of a particular pedagogical reform in a singular setting, the tools often are not effective across multiple sites or with multiple instructors (Fairweather & Paulson, 2008). Previous research has shown that the such successes are usually isolated to a single instructor, with little institutional or inter-institutional dissemination, or are the result of specific institutional commitments who's effects are transitory and localized (Eiseman & Fairweather, 1996; D. Fisher, Fairweather, & Amey, 2003). Pedagogical innovations often die out because of the extra time investment they require in preparation and training over traditional methods such as lecture (Labov, et al., 2009). However, Fairweather (2008) notes that, "The key to improving STEM undergraduate education lies in getting the majority of STEM faculty members to use more effective pedagogical techniques than in now the norm in these disciplines" (p. 13). Because of it's ease of use and implementation, and it's scalable applicability, the Case It! project has the potential to bridge this gap.

The finding of instructor independent efficacy also reinforces Pascarellea and Terenzini's assertion that the most effective pedagogical strategies in pedagogical reform are not discipline dependent (2005). Recent research has shown that active and collaborative learning environments that motivate and engage students will result in increased performance regardless of discipline (Kuh, et al., 2007; Kuh, et al., 2005). This suggests that the Case It! program, or a derivative of it could be usefully and successfully applied in across a wide spectrum of STEM fields.

An updateable pedagogy. Textbooks and publisher provided ancillary materials have an inherent lag time associated with the information they provide because of the speed of publishing paper-based products (e.g. Knight, 2007; Yore, 1991). With the ever-increasing rate of discovery within STEM fields, and the rapid incorporation and implementation of new techniques and methods, instructors require learning environments that are capable of keeping up with the pace of innovation—and textbooks just cannot do that. Because the Case It! learning environment is digital, updating both the information and data contained within it is a relatively simple process. It is also possible to modify the existing lab methodology to incorporate emergent tools in the field such as bioinformatics. In this study, students were motivated to learn because they were using cutting-edge techniques and material that wasn't incorporated into their texts. The end result of using Case It! is a much shorter time-to-learner gap in information, enabling both students and instructors to learn on the leading edge of their fields, rather than 2-3 years behind as is the case with most texts.

Motivation inherent in Case It!

The Case It! program is a case-based, virtual learning environment used to investigate infectious and genetic disorders, and designed to stimulate student interest in science. The program utilized a mixture of epistemological approaches that engaged students on multiple personal, professional, ethical, and social levels. This study of the learning environment demonstrated that it can have a significant impact on student motivation by engaging students at all 4 levels of Keller's ARCS model of motivation (Keller, 1987, 2010) and because it results in high products for the Expectancy x Value model (Brophy, 2004; Wigfield & Eccles, 2000). In motivating students, the Case It! project demonstrated significant ability to influence student performance, learner attitudes, and programmatic retention.

Attention. Case It! captures students' attention in several ways. One of the primary methods is via the case studies, especially the video cases, which represent a novel method of introduction to material for most students, and provide sensory stimuli. A common comment from students was that the cases piqued their curiosity about a disorder by providing concrete references to real individuals, and creating a sense of mystery by providing incomplete snapshots of stories that leave the endings up to the students' investigation (Keller, 2010). By presenting "real-world" situations that were inherently problematic, Case It! encouraged students to probe deeper into the material, ask questions, and satisfy a desire for further inquiry. Additionally, the project created cognitive dissonance for some students by contrasting their perceptions of reality against actually demonstrations of reality—especially with HIV cases. Comments demonstrate that by constantly varying the learning situations for students (e.g. case to virtual lab to creation of a poster, etc...), attention was maintained.

Relevance. As was noted earlier, relevance is of vital importance in maintaining student attention, motivation, and persistence (Aikenhead, 2006, 2007; Wolter, Lundeberg, et al., 2009), and was an area where students reported Case It! excelled. Comments show that the overall worth of the project was demonstrated by relating it to society, personal application, and professional ambitions. Case It! connected content knowledge learning scenarios with students' salient life experiences, both past and present, developing a degree of personal relevance. Many students noted this, stating that they developed a personal connection with the characters in the cases, and by extension the material. Others described a feeling of moral obligation to demonstrate competence because cases were base on real people and the students wanted to provide accurate information for these individuals. These personal connections and altruistic feelings were indicators that the project developed psychological relevance for many students, which included the codes of "need-to-know science" (information for potential personal use) and "functional science" (information for potential vocational use). Case It! also engaged students in situations where they could envision themselves as practitioners of science, and where they reported feeling integrated into the overall scientific community.

The autonomous nature of the project allowed students to individualize their experience, exercising self-determination to make the encounter relevant, personal, and wholly their own. This ability to direct their own paths of learning piqued some students' curiosity about tangential issues and knowledge. Keller (2010) calls this desire for independent exploration "situated intrinsic motivation" (p. 118) in which students develop interests along several avenues of thought divergent to that of content mastery. Also related to the issue of autonomous learning in Case It! were a few student comments ($n = 3$) about relevance created by the *flow* (Csikszentmihalyi, 1975) of the learning environment. Keller describes this as, "…being completely absorbed in an activity to the point that you are not conscious of distractions…" (Keller, 2010, p. 120). This phenomenon manifested itself most often during role-playing.

Confidence. Case It! contributed to student perceptions of self-efficacy by providing students with a forum in which to demonstrate their knowledge to others *and to themselves* (Bandura, 1997; Schunk & Pajares, 2009). By doing so, the project intrinsically boosts students' confidence in both their skills and their ability to apply theoretical knowledge (e.g. Brophy, 2004; Glynn, et al., 2005). This same forum afforded students the opportunity to develop communication skills and content mastery by serving as translators of information between communities with frequently disparate cognitive perspectives and priorities (i.e. physicians and family members). Other opportunities for success developed for students because the project allowed them to practice complex and time consuming lab procedures in a "safe" environment, where making mistakes and time were not negative factors. Finally, the project built student confidence because it allowed students to take personal responsibility for content, and by extension ownership of the project (Keller, 2010; Keller & Suzuki, 1988).

In general, student confidence is desirable since it builds perceptions of self-efficacy and situational control. However, because students become so immersed in the project it is also possible for them to become overconfident in their knowledge, leading to content arrogance and reduced performance. This is exemplified by the across the board increase in student answer confidence from pre- to post-test, even though they demonstrated significant improvement on only 4 of the 6 questions. Class specific results demonstrate an even more stark result, such as at UWRF-M where there was actually a *significant decrease* in performance on question 1 from pre- to post-test, even though student confidence *rose significantly*. Instructors utilizing Case It! need to keep in mind the potential for student overconfidence and adapt.

Satisfaction. Students overwhelmingly stated that they thought the Case It! project was a worthwhile learning endeavor (95%), indicating a high level of satisfaction. This level of approval was the product of several fundamental tenets. First, Case It! provided students with a quality instructional environment where the value of content was readily evident (Aikenhead, 2007; Keller, 2010). Second, the project provided intrinsic reinforcement in the form of feedback from peers in conferencing that developed perceptions of accomplishment and desire to learn more (Keller, 2010; Keller & Suzuki, 2004; Renchler, 1992). Third, it allowed students to apply theoretical knowledge gained over years of study under realistic conditions where their actions mattered to the outcome for real individuals (Brophy, 2004; Koper & Tattersall, 2005; Merrill, 2002). Fourth, in association with learning under realistic conditions, the project provided a forum for students to begin to develop a sense of scientific identity, and to place themselves within the context of the overall scientific community (Brown, 2004; Brown, Reveles, & Kelly, 2005; Reveles, Cordova, & Kelly, 2004).

Expectancy x Value. While the vast majority of students in this study found value in the project, student expectations were somewhat muddier and influenced by important external factors. Expectancy values were variable depending on the student population sampled. Some students reported the use of computer modeling made the project unnecessarily difficult, lowering their expectancy; other students said the virtual environment was beneficial, resulting in higher expectancy values. Expectancy also appears to have been affected by student level, with upper division students anticipating greater gains from the project than those in introductory courses. The value of rewards and engagement provided by the Case It! project were high according to interviews, with students referencing both personal and professional significance in the exercise. In general, students appear to have engaged (Brophy, 2004; Hansen, 1989) with the project; in this context meaning that they recognized the overall value and were reasonably expectant of success. Thus, one can conclude that the Expectancy x Value product of the Cast It! project is relatively high.

Both the ARCS and Expectancy x Value models of student motivation may be applied to the Case It! project; however, it also embodied aspects not identified by either model. Case It! was more than just case-based instruction environment that developed attention, relevance, confidence, and satisfaction. It allowed students to develop ideas from theory through analytical application and into social application.

Limitations

This study can begin to draw some conclusions about how students interact with a multimedia case study learning environment, and how the experience may impact pedagogical reform in STEM programs, but one must be careful not to extrapolate the findings too far. One of the main concerns with research that relies on self-reporting is that students may not be aware of changes in their perspective, of learning more, or decisions relating to remaining in STEM fields. Such changes are often subtle, and difficult to attribute to any single experience. A thorough examination of students' answers on each test item was not conducted, so no specific knowledge of what they do or do not understand was generated. I can only say that they did poorly on some items in relation to others.

While the students who participated in this study were demographically representative of their respective institutions, there is no way to be sure that their opinions and performance represent the actual central tendency. As with any other mainly qualitative study, these results are not generalizable to American higher education population as a whole; however, they form a useful starting point from which further investigation may be launched. While this is a relatively large-scale qualitative study, it only accesses three ethnic populations in postsecondary education. Further research incorporating other population subgroups such as western Latinos, Native Americans, Native Alaskans, Native Hawaiians, and/or Asians to name a few, is necessary to further investigate the efficacy of multimedia, case-based instruction as an instrument for increasing STEM retention in these minority groups. Additionally, although the author hoped to triangulate findings by using multiple methods, some methods such as member-checking and in-depth personal interviews could not be utilized due to both time constraints and logistical considerations.

The overall sample size and participation rates are limitations. It was hoped that the majority of students in each class tested would participate in the study, yielding a sample size of over 100 students; however, participation rates were extremely variable, ranging from 23-95%. Future studies would benefit from sampling courses in heterogeneous environments, hopefully resulting in demographics comparable to the general higher education population structure.

Future research

The current study investigated how a multimedia, case-based learning environment influenced student retention in both introductory and upper division biology classes. Several avenues for future research in retention are possible. Many junior and senior level participants in this study answered that while Case It! did reinforce their desires to be science majors, very little could influence them to change majors at this time point because they were already so invested. Students at all levels commented that they thought the project would be effective in boosting enrollment and persistence in science programs if applied either in high school or introductory courses. Studies have shown that freshman decisions and the first year in STEM programs is critical to retention (Daempfle, 2003-2004; National Science Foundation, 2002; National science Foundation, 2007). To test the upper division students' perceptions, I believe it would be fruitful to conduct further studies of the Case It! learning environment across a broad spectrum of introductory level biology classes. Ideally these studies would include both majors and non-majors level courses in order to access the largest sample of potential STEM students. A large number of study sites (10+) representing a cross-section of modern American higher education institutions (e.g. community college, liberal arts, comprehensive, etc...) and student population structures would also be desirable, but such breadth would likely be hindered by funding issues. In this study, intentions to persist might be measured using surveys administered at strategic times throughout the freshman year, (a) arrival on campus, (b) at the end of fall semester, and (c) at the end of spring semester, to present a limited longitudinal picture of retention in program. The student survey used in this study could be modified to do this.

This study corroborated that *context matters* to students (Lundeberg, et al., Under revision). How information is presented is at least as important as what information is. The connections students said they made with the content are worthy of further consideration, especially how they influence motivation. Developing a study that more deeply assesses the roles of student relevance and satisfaction in Case It! might be able to further this discussion.

Exploring the Case It! project's potential to access and motivate students of different cultures should also be considered. More than 115 colleges and universities from 39 countries have downloaded this program, so there is obvious cross-cultural appeal to the idea of using cases in multimedia environments. Students in this study sometimes had very different perspectives on what aspects of Case It! were relevant to them and how they were. Based on this, I believe a cross-cultural study of student perceptions of relevance would be useful in understanding how to make science more appealing to students of diverse backgrounds. Such a study would likely start by exploring the perceptions different cultural groups represented within North America (e.g. Native American, Asian-American, Pacific Islanders, western Latino, etc...) using methods similar to this study, and could potentially be expanded to international sites.

Student motivation has an effect on both comprehension and program retention (Allen, 1999; Theall & Franklin, 1999). In an era when student bodies are becoming increasingly diverse and complex (Duderstadt, 2000; Pryor, et al., 2008), it is worthwhile for STEM programs to ask what motivates students of diverse backgrounds to choose science as a course of study, and how can programs use this information to attract a more heterogeneous student body?

The differences in performance and perception noted in this study between sites may be artifacts of small sample populations. Future studies interested in examining these relationships should select sites that are heterogeneous and that can either offer high participation rates or class sizes large enough to ensure adequate sampling. For example, many California universities have highly diverse student bodies, large overall enrollments, and several currently use the Case It! learning environment. Targeted studies of specific populations, like Native Americans, could be coordinated by cross-referencing statistics from the Integrated Postsecondary Education Data System (IPEDS) with schools currently using Case It! Examining the effects of Case It! on student retention in STEM fields outside of biology could contribute salient and interesting comparisons; however, this would require a significant amount of work by the developers to expand the program.

Implications for practice

This study is significant because it explores and establishes the efficacy of a scalable, case-based, multimedia learning environment on student performance, persistence, and opinions in undergraduate STEM education.

Agencies. The Case It! learning environment is an especially effective way to distribute and familiarize students with complex content and lab processes. Because it is a digital forum, it can easily be updated by both developers and practitioners to incorporate cutting-edge techniques and content. Unlike many pedagogical tools developed to improve undergraduate STEM education, the Case It! project is effective regardless of teacher, student level, institution, gender, and language. It is a tool that can be easily adopted for use from secondary through postsecondary and even graduate education. The Case It! project is also applicable in a wide-array of courses and subject matters, demonstrating both its flexibility and pedagogical strength. Because the learning environment develops student perceptions of self-efficacy, emotionally involves students, and establishes the relevancy of content to students, it also has the potential to positively influence student persistence in STEM programs.

Faculty who teach undergraduate science. A common statement from students was that Case It! is an easy program to use, and this holds true for both learners and instructors. The project easily lends itself to use in multiple courses, at several grade levels, and with an array of subject matter, making it an effective and useful tool for instructors. Student comments demonstrate that Case It! is both an engaging and motivating learning environment for students. Over 95% of students said they found the experience to be worthwhile, demonstrating that it establishes relevancy and interest for learners across a broad spectrum of cultural, social, linguistic, and preparation levels. Another benefit of Case It! is that it allows students to incorporate and apply knowledge from multiple sources and multiple classes in a single, real-world experience, allowing them to understand connections between subject areas they had perhaps considered unrelated. An example of this would be that when creating their webposters, many students pulled together information about immunology, ecology, nutrition, health care, and socio-cultural issues. Again, Case It! is applicable with multiple learning levels and in many different classes.

Conclusions

The purpose of this study was to explore one potential method to reform poor pedagogical practice in undergraduate STEM education nationally (e.g. Seymour & Hewitt, 1997). I sought to answer one main question: Does using a case-based multimedia project affect postsecondary students' performance or motivation to learn biology?; and two sub-questions about this intervention's utility: (a) Does participation affect persistence? and (b) Is Case It! a beneficial learning experience?

Not enough students are entering postsecondary STEM programs in the United States today (Augustine, et al., 2006). Aikenhead (2007, p. 885) notes that science education at the collegiate level is experiencing a "...chronic decline in student enrollment due to students' disenchantment with school science," a fact that has been acknowledged for decades (Dekkers & Delaeter, 2001; Hurd, 1989; Welch & Walberg, 1967). While there are any number of conclusions as to why this may be, research on humanistic perspectives asserts that this is because students do not feel connected to the science they learn and view it as sterile and impersonal. Numerous studies have shown that *how* material is taught impacts both student interest and perceptions of relevancy (Herreid, 2005b, 2006a; Lundeberg, et al., 2002; Sokolove, et al., 2003; Wolter, Kang, Lundeberg, & Herreid, 2009; Wolter, Lundeberg, et al., 2009). The multimedia, active-engagement pedagogy used by the Case It! project appears to not only increase student performance, perceptions of relevancy, and overall topic interest, but also have a positive influence on student motivation and therefore STEM student retention.

The Case It! project does not, and cannot, independently solve the issues of student performance in STEM programs, but it does provide useful insight into one method to beneficially impact both performance and retention. Data presented here indicate that the use of such pedagogical techniques might be best employed at the introductory level when students are first making decisions about major programs, although projects like Case It! may exert limited influence on persistence at the upper division level. Seymour and Hewitt (1997) noted that one of the biggest factors affecting student decisions to leave STEM programs was poor instructional quality, and student responses to questions in this study reinforce that. Participants overwhelmingly liked Case It!, and repeatedly said that they appreciated the dynamic and interactive approach to instruction that it employs. This study informs the discussion on the role of instructional method on student retention in STEM fields, demonstrating that students appreciate contextualized, "real-world" scenarios where they can envision themselves as practitioners and gain applied experience. Students also like being able to see the "bigger picture," and how all the material they are learning fits together in a real-world environment.

Appendix A

Case It! Performance Test

Student ID: ______________________

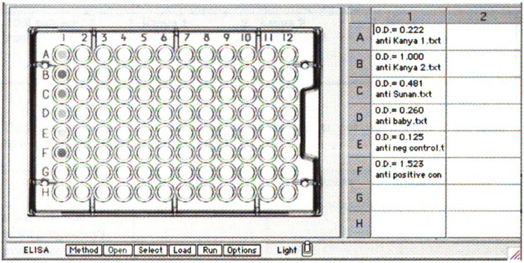
Gender: Male / Female

Ethnicity: Latino African-American Caucasian Asian Other

Section: ___________________

After recording your answer, please indicate how confident you are that your answer is correct on a scale of 1-5, with 1 = very uncertain and 5 = very confident.

Kanya is a 24-year-old woman in Bangkok, Thailand, who just gave birth to her first child. She and the baby's father, Sunan, had been tested for HIV several weeks before she became pregnant. She had a second HIV test as part of the routine blood work during her fifth week of pregnancy. The infant was tested three weeks after her birth. The ELISA results for all of these tests are shown below.



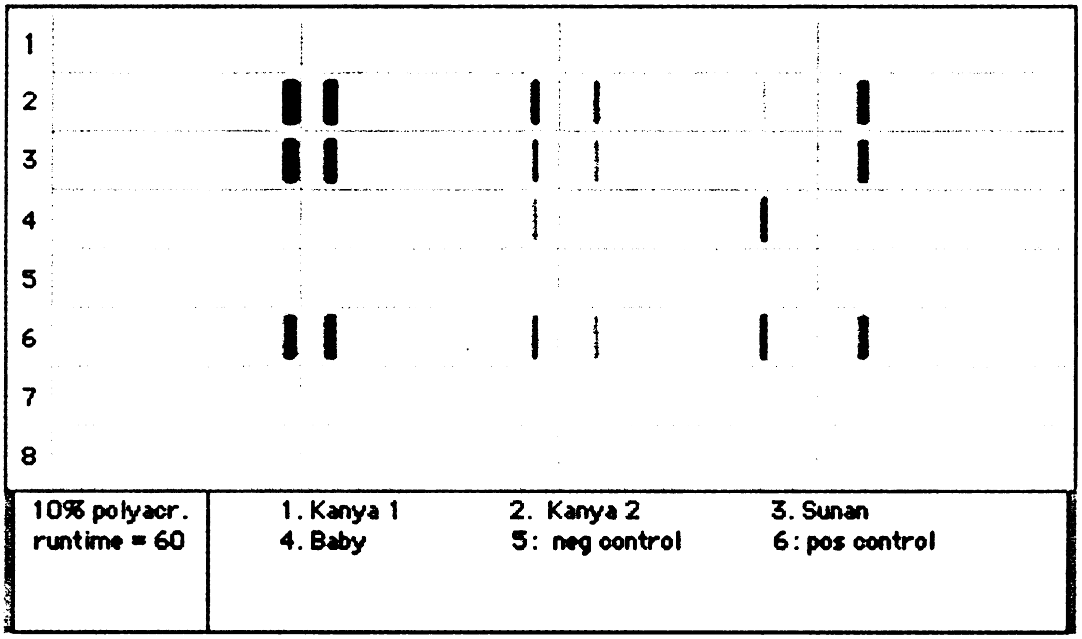
1. How would you interpret these results? Check the appropriate box for each test sample:

	HIV positive	HIV negative	Indeterminate
Kanya, first test (before pregnancy)			
Kanya, second test			
Sunan			
Baby			

How confident are you in your answer? 1 2 3 4 5

1 = very uncertain and 5 = very confident.

A Western Blot was run as a follow-up after each of the above tests. A composite of the Western blot results is shown below:



2. Based on both the ELISA and western blot test results, put checkmarks in the table below to indicate the HIV status of each person.

	HIV positive	HIV negative	Indeterminate
Kanya, first test (before pregnancy)			
Kanya, second test			
Sunan			
Baby			

How confident are you in your answer? 1 2 3 4 5
Very uncertain Very Confident

3. Why run both an ELISA and a Western Blot to test for HIV?
Put checkmarks in the table below indicating to which test each feature applies.

Feature of test	Western Blot	ELISA	Both WB and ELISA	Neither
A first screening test for HIV				
To isolate a specific HIV gene				
Tests for HIV antibodies				
The bands between Ribosomes and DNA				
The more definitive test for HIV				
Amount of virus in blood				
HIV proteins separated by size on gel				

How confident are you in your answer? 1 2 3 4 5
Very uncertain ... Very Confident

For these next 2 questions, put yourself in the role of an HIV counselor in Thailand. How would you explain the test results? What advice would you give them? Include social, medical and ethical advice. Do not try to write complete sentences; just list the main points you would include.

4. What would you say to Kanya and Sunan about their test results?

How confident are you in your answer? 1 2 3 4 5

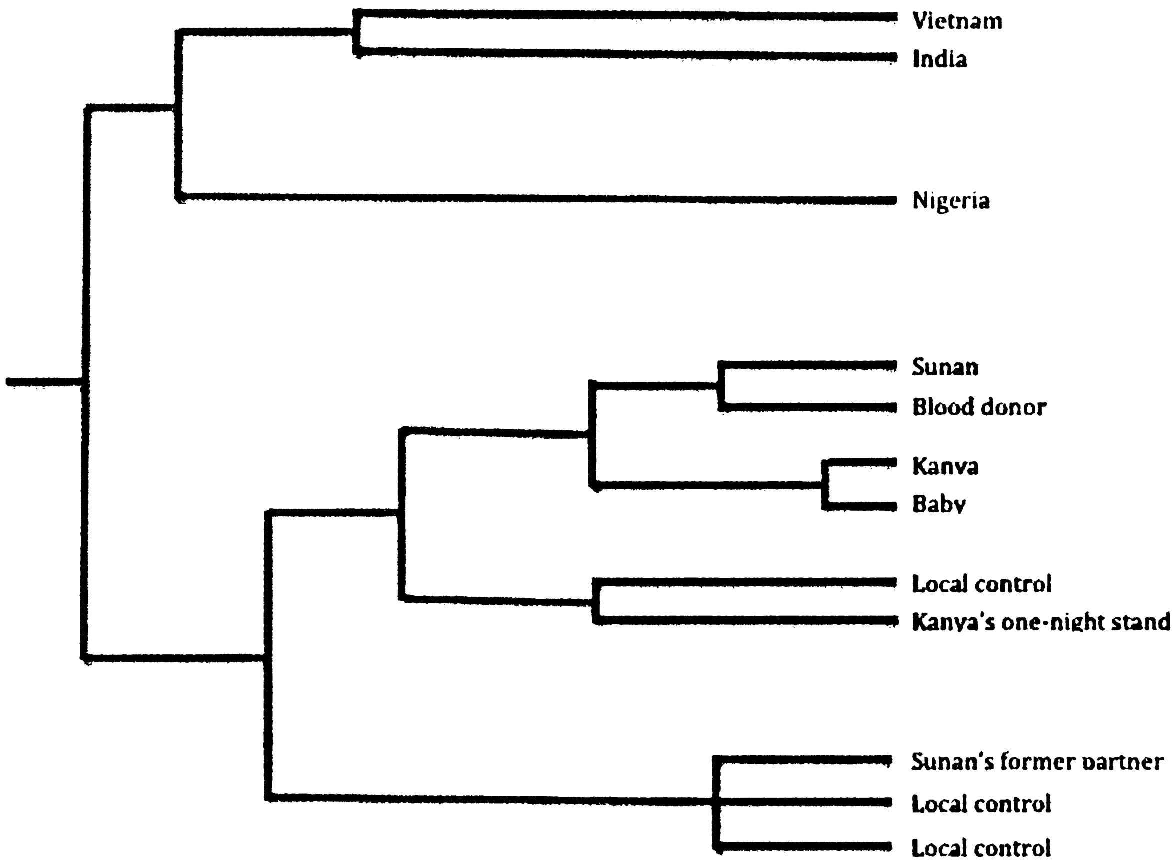
Very uncertain — Very Confident

5. What would you say to Kanya and Sunan about the baby's test results?

How confident are you in your answer? 1 2 3 4 5

Very uncertain — Very Confident

6. Study the tree below that shows HIV sequence comparisons for these individuals: Kanya, Sunan, their baby, Kanya's one night stand, the blood donor from a transfusion Sunan had, Sunan's former partner, and HIV sequences from India, Nigeria, and Vietnam. How do you interpret these results? What would you tell Kanya and Sunan about how they contracted the HIV virus?



How confident are you in your answer? 1 2 3 4 5

Very uncertain ... Very Confident

Appendix B

Case It! Student Survey

Student name: ______________________________

Please answer the following questions briefly. You will have the opportunity to expand upon your responses during the focus group interview.

We appreciate your participation and cooperation in improving the Case It! experience.

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1. **What do you plan to do in your future career? Please check on or more…**

Physician	Other healthcare	Teacher	Food science
Biotechnology	Research	Conservation	Forestry
Medical technology	Forensics	Veterinary medicine	Other (please list)
Nurse	Agriculture		

2. **Do you think your experiences with Case It have helped prepare you for future classes or a future career?** **YES** **NO**
   Please explain.

3. **My experiences with Case It! have reinforced my desire to continue to be a science major**

   1 (not at all) 2 3 (somewhat) 4 5 (quite a lot)

   Please explain your answer.

4. **How interested were you in your case topic before starting the project?**

   1 (not at all) 2 3 (somewhat) 4 5 (quite a lot)

   How interested were you in your case topic after completing the project?

   1 (not at all) 2 3 (somewhat) 4 5 (quite a lot)

   Please explain.

5. **Was this project relevant to your life?** **YES** **NO**
Please explain.

6. **How confident are you in your knowledge of the disease you studied for your case?**

1	2	3	4	5
(not at all)		(somewhat)		(quite a lot)

Please explain your answer.

7. **Please rank the 2 most valuable learning components of Case It! for you.**

Virtual lab	Bioinformatics	Webposter creation
Role-playing	Conferencing	Internet research

Please explain.

8. **How useful did you find the role-playing aspect of Case It! in helping you learn the material?**

1	2	3	4	5
(not at all)		(somewhat)		(quite a lot)

Please explain your answer.

9. **Please rate your experience with role-playing as a family member**

1	2	3	4	5
(disliked it)		(neutral)		(enjoyed it)

Please rate your experience with role-playing as an HIV councilor.

1	2	3	4	5
(disliked it)		(neutral)		(enjoyed it)

Please rate your experience with role-playing as a bioinformatics researcher

1	2	3	4	5
(disliked it)		(neutral)		(enjoyed it)

Please rate how much you learned from role-playing

1	2	3	4	5
(nothing)		(neutral)		(quite a bit)

Please elaborate on your answers.

10. Was this project a good learning experience for you? YES NO
Please explain.

11. Please share any additional thoughts about Case It.

Appendix C

FGI QUESTIONS

1. Do you think your experiences with Case It! have helped prepare you for future classes or a future career?

   How so?

2. Has your experience with Case It! affected your desire to continue to be a science major?

   In what ways?

3. Did participating in Case It! increase your interest in the topic?

4. Was this project relevant to your life?

   How?

5. How confident are you in your knowledge of the disease you studied for your case?

   Why?

6. What was the most valuable component of Case It! to you?

7. How useful did you find the role-playing aspect of Case It! in helping you learn the material?

8. Did you enjoy the role-playing?

   Why or why not?

9. Was this project a good learning experience for you?

   How did it help you learn science?

10. Do you have any additional thoughts or comments about case it! that you'd like to share?

Appendix D

Participant Consent Form

This study investigates the impact of multimedia case-based learning on university students' perceptions, understandings, and confidence in their knowledge of infectious diseases and genetic disorders using the Case-It! software. The cases will consist of narratives regarding individuals with infectious diseases and genetic disorders. As part of the Case-It! multimedia environment, students will be involved in using an simulations, creating and presenting web posters, and role playing, all as part of their coursework. A pre- and post- assessment with information from the simulation will be used to gather information about students' knowledge about infectious diseases and genetic disorders as well as their ability to interpret data from ELISA, Southern and Western-blot, and bioinformatics simulations. Participants will be interviewed regarding their perceptions about cases after they complete their work.

Your participation in the study will consist of giving us permission to use your coursework. Your permission to use your coursework would include items such as the web page you create with your results from the Case-It! simulation, the electronic transcripts from computer conferences you engage in about the web page, and written responses to in-class assignments on molecular diagnostic testing before and after the use of the Case-It! software. We also have a short survey we would like you to complete about your knowledge and perceptions of infectious diseases that will be completed in class, and we will also invite you to be part of a focus-group interview. Please note that we will not use student names or other identifying information in any reports of this research.

All data will be treated with strict confidence and your name will not be used in any report of the research findings. Your responses to questions are confidential (not anonymous). Your privacy will be protected to the maximum extent allowable by law. If you would want to know the results of the study (within these restrictions) you should leave your name with us. Your decision to participate or not participate in the research will have no effect on your grade or any future recommendation your instructor may make.

Participation is voluntary. You have complete freedom to discontinue the study at any time without penalty. You have the freedom to not respond to certain items. If at any point you feel any discomfort with the materials or questions please do not hesitate to stop us.

If you have any questions about this study feel free to contact:

Bjorn Wolter	Dr. Mary Lundeberg
517.507.5896	517.353.5091
bwolter@msu.edu	mlunde@msu.edu

If you have any questions or concerns about your role and rights as a research participant, or would like to register a complaint about this research study, you may contact, anonymously if you wish, Michigan State University Human Research Protection Program at 517-355-2180, FAX 517-432-4503, or e-mail irb@msu.edu, or regular mail at: 202 Olds Hall, MSU, East Lansing, MI 48824.

Your signature below indicates your voluntary agreement to participate in this study.

Name: (printed) ______________________________

Signature: ______________________________ Date: ____________________

I agree to be video-recorded in this study if I consent to an interview.

Signature______________________________Date: ____________________

Appendix E

Rubric for Performance HIV Assessment (Pre/Post - 26 pts)

1. **Give the HIV status of each person based on the ELISA (Put 1 or 0 for each person)**

Kanya1 (First Test):	HIV Negative	
Kanya2 (Second Test):	HIV Positive	
Sunan	HIV Positive	
Baby	Indeterminate	

Correct Interpretation = 1 point each; Incorrect = 0; Total possible = 4
Student's score =________ Confidence = __________

2. **Give the HIV status of each person based on both the ELISA & Western Blot**

Kanya1 (First Test):	HIV Negative	
Kanya2 (Second Test):	HIV Positive	
Sunan	HIV Positive	
Baby	Indeterminate	

Correct Interpretation = 1 point each ; Incorrect = 0; Total possible = 4
Student's score =________ Confidence = __________

3.

Feature of test	Western Blot	ELISA	Both WB & ELISA	Neither
A first screening test for HIV		**X**		
To isolate a specific HIV gene				**X**
Tests for HIV antibodies			**X**	
The bands between Ribosomes and DNA				**X**
The more definitive test for HIV	**X**			
Amount of virus in blood				**X**
HIV proteins separated by size on gel	**X**			

Total points possible = 7
Student's score =________ Confidence = __________

4. **HIV Counseling**

Model advice for 4 pts
This questions aims to examine students understanding of the medical as well as ethical implications of giving advice to people who have HIV.

For 4points – Model response includes information about all three family members and information regarding medical treatment, ethical implications, and resources to family

For 3 points – Model response includes information about 2 family members and either a medical and/or ethical advice/resources to family.

For 2 points – Model response includes 1 family member and either medical and/or ethical advice/resources to family

For 1 point – model response is a general explanation of medical treatment and ethical advice

For 0 points – No advice, no explanation, general lack of understanding

Model Response: For both Kanya and Sunan, their results are positive which means they have the Human Immunodeficiency Virus (HIV), which causes AIDS. This virus is transmitted through contact with body fluids. With HIV, almost all infected people eventually develop disease symptoms, but it may take several years. However there are medications that can help reduce virus multiplication in the body and hence can prolong your life. It is advisable that they immediately see the doctor and get to know what treatment options are available. There is also need for the couple to stay healthy by eating foods that are rich in nutrients in order to boost their immunity and to exercise regularly. They should also avoid sharing needles and practice safe sex to avoid infecting others and to avoid re-infections.

Score: ________

Confidence : _____________

5. **HIV Counseling**

Model advice for 4pts.
This questions aims to examine students understanding of the medical as well as ethical implications of giving advice to people who have HIV.

For 4points – Model response includes information about all three family members and information regarding medical treatment, ethical implications, and resources to family

For 3 points – Model response includes information about 2 family members and either a medical and/or ethical advice/resources to family.

For 2 points – Model response includes 1 family member and either medical and/or ethical advice/resources to family

For 1 point – model response is a general explanation of medical treatment and ethical advice

For 0 points – No advice, no explanation, general lack of understanding

Model Response: The Baby's results are indeterminate, which means they are not conclusive. This may be due to the fact that baby still has antibodies from the mother. Baby needs to be tested again in order to determine its status. For now there is need to ensure that baby s not infected through breast-milk or the parents' body fluids.

6. Bioinformatic interpretation (3 Pts)

This question is intended to determine how well students can interpret a bioinformatics tree.

How do you interpret these results? The infection source is the blood donor **(1 pt)**

What would you tell Kanya and Sunan about how they contracted the HIV virus?

For 2 points – includes an explanation of the infection source, how infection occurred, and what this means for them.

For 1 point – simple cites the infection source without explanation.

For 0 points – no explanation, general lack of understanding.

Score: _________

Confidence : ______________

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