

Using Case Study Instructional Methodology in High School Biology:
Its Effect on Cognitive Engagement and Critical Thinking Skills

by

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Abstract

The purpose of this study was to examine the effect that case-based instructional methodology had on student's development of critical thinking skills, cognitive engagement and learning as compared to the lecture-based instructional methodology. The experimental design consisted of two grade 12 high school biology classes being taught a unit of study with two different teaching methodologies. Each class was taught half the unit with case-based instruction and the other half of the unit using lecture-based instruction. The two classes were taught opposite halves using these instructional methodologies.

The Applied Critical Thinking Measure was used to determine the students' level of development of their critical thinking skills. The measure consisted of five scenarios that required students to read, identify the objective, ask questions that would clarify their understanding, draw upon existing information or list new information needed, and draw a conclusion with supporting statements. Cognitive engagement was measured by direct observations using a criterion checklist of 14 items. The teacher-researcher and her colleague designed three artifacts to measure student learning.

T-tests were used to compare the mean scores of the two classes on each of the artifacts collected for student learning. The inferential statistics showed that student learning improved during the case-based teaching section of the unit. The observations showed an increase in cognitive engagement during the case-based instructional section of the unit. There was no significant difference in the mean scores for students' critical thinking skills in Class 1, but there was a significant difference in the mean scores for

Class 2. The difference appears modest but considering the duration of the study it is a notable development.

The scope of this study addresses a knowledge gap regarding the use of case-based teaching methodology in high school. The implications are meaningful in that case-based teaching has shown to have an impact on cognitive engagement and student learning in a high school biology classroom.

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Chapter One: Introduction

Twenty-first century society requires citizens to be dynamic purposeful thinkers who are able to analyze situations and use their knowledge to make well thought-out and informed decisions. The students we are teaching are the future and, as such, need to be able to think independently and critically to be successful (Lee, 2013). It is a responsibility of the education system to play a role in preparing students to become purposeful citizens in a rapidly changing world.

Being an effective teacher who meets the needs of all students requires using a variety of teaching approaches to present the curricular outcomes relevant to a course. However, in today's technologically advanced and changing world, this means a great deal more than just teaching students the content. If they are to become productive citizens they need to be taught the skills necessary to become better thinkers and decision makers. This involves teaching critical thinking skills (Chiras, 1992). These skills include but are not limited to asking insightful questions, finding relevant information, analyzing and scrutinizing evidence, making inferences, and supporting conclusions drawn. Critical thinking is an active process that requires the students to engage and participate in the activity if they are to become adept with the skills. Costello (1996) suggests that critical thinking skills and the ability to argue or make a judgment based on knowledge are important parts of the students' education as these are the skills that help them develop into informed, productive citizens in our society.

As Benjamin Juarez so eloquently stated, We are "in a time when young people will not only have to change jobs, but change professions several times in their lives," he says, "the advantages of a university education that is centered and focused on creative

thinking and critical thinking will be the best tools to thrive and to be successful” (BU Today, 2011). The Wingspread Conference in 1994 brought together several leaders from various state, federal and educational organizations. They reported that the characteristics needed from graduates should include:

[I]mportant high-level skills in communication, computation, technological literacy and information retrieval that would enable individuals to gain and apply new knowledge and skills as needed... [T]he ability to arrive at informed judgments by effectively defining problems, gathering and evaluating information related to those problems, and developing solutions; the ability to function in a global community; adaptability; ease with diversity; motivation and persistence; ethical and civil behavior; creativity and resourcefulness; technical competence; and the ability to work with others, especially in team settings. (Savery, 2006, p. 17)

The Conference Board of Canada (2014) outlines similar skills that they believe individuals will need when they enter and wish to “progress in the world of work – whether you work on your own or as part of a team.” The skills are divided into key categories which include fundamental skills, personal management skills, and teamwork skills. There are several competencies that are identified for each category. These include, but are not limited to communicating, managing information, thinking and solving problems, demonstrating a positive attitude, being responsible and adaptable, working with others, and being a lifelong learner (Conference Board, 2014).

The education system has a responsibility to foster these skills before students enter the workforce. The current biology curriculum for Manitoba includes clusters of

general outcomes that support the development of the aforementioned skills. Moreover, the Grade 12 Biology: A Foundation for Implementation (Manitoba Education, 2011) document places emphasis on inquiry-based learning that requires investigating, communicating, analyzing, and synthesizing data. These are some of the goals being endorsed in the science field to help students become more scientifically literate citizens. The role of teachers is to integrate these skills into their teaching on a regular basis if they want students to be successful in utilizing them.

Students very often do not see a connection between themselves, their lives, and the content they are taught throughout their high school education. They explain their disengagement as a result of the insignificance of their coursework with their future plans (Willms, 2003). Educators can help the students create the scaffolding necessary to make these connections. A multinational study showed that “students’ engagement in science improved when the curriculum dealt with contemporary issues, a teaching style that was less didactic and allowed for students voice” (Hampden-Thompson, 2013, p. 1327). Research has shown that the most engaging type of activity involved students being autonomous, collaborating with peers, and actively participating. By exposing students to ‘real world’ scenarios they can apply their knowledge and skill sets and see the relevance.

Newmann (1992) outlined four qualities in the real work world that were missing in school work: 1. Value beyond the initial instruction, 2. Clear and immediate feedback, 3. Collaboration, and 4. Flexible use of time to solve problems in their own way. Although progress has been made in providing students with more immediate feedback and collaboration with peers by utilizing cooperative learning strategies, there is still a

gap in demonstrating the relevance of the course content beyond the classroom. McClure (2012) explained that we can stimulate interest by showing students the content's real-world connections and by involving them in activities that inspire creative applications.

Teaching a student to become a productive citizen involves engaging the student in his course work so that he is able to develop analytic and critical thinking skills in order to problem solve. As a high school science educator, I am aware that the traditional lecture teaching format does not engage all students or provide them with the opportunity to learn and practice critical thinking skills. "Studies reveal that engagement may be as low as 45-50% in some classrooms" (Christenson, 2012, p. 653). The use of different teaching methods may allow for the majority of students to engage more readily in the coursework. As Dale introduced in 1969 in the 'Cone of Learning', students will remember "10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they hear and see, 70% of what they say and write and 90% of what they say as they do a thing" (Lord, 2007). This supports the importance of active learning for the student to retain the knowledge being taught.

Case studies are one significant way of providing this opportunity for students (Hampden-Thompson, 2013). For an experience to be genuinely engaging, Hagel, Carr & Devlin (2011) say that students must not only have autonomy, but also choice and some control over the topic. Case studies are stories or narratives that provide background information and generate questions that can result in students solving a form of problem or applying their knowledge to answer the scenario represented in a case. This type of methodology gives the students the opportunity to choose a role or develop an opinion and proceed through the task. A specific type of case study that does this well

is the Intimate Debate Method. It allows the student to research, support and defend his position about a particular topic.

Veselinovska (2011) indicates that the traditional lecture or oral presentation method of the teacher presenting information to a large passive group of students contributes very little to real learning regardless of the discipline. Students have a wide range of learning styles. The lecture-based approach has been shown to be an effective learning method for some students, but it does not meet the need of engaging all students. It is for this reason that educators need to employ multiple teaching methodologies in their programs.

Case studies provide a rigor to a task because they incorporate deep thinking and analysis, they allow for the creation of generalizations and measurement against other criteria, and they may require multiple attempts to get a viable solution or answer (Zmuda, 2010). Research supports the claim that interesting assignments, student collaboration, high academic expectations, and participation in groups make a positive contribution to student success (Willms, Friesen & Milton, 2009).

Employing the use of case study methodology is said to promote questioning, reflection, observation, collaborative discussions with peers, as well as independent learning (Herreid, 2013). Authentic or meaningful tasks not only allow the student to become engaged at the specific discipline level, but they also have long term benefits to create powerful learning outside of the school setting (Zmuda, 2010). This powerful learning occurs in the opportunities that develop for the students as a result of the skills they learn while being engaged in their coursework.

The advancements in the field of biology are substantial given the significant improvements in technology. It is current students who will be the users of this knowledge. We need to provide them with the skills to make decisions based on sound judgment that involves critical thinking (van der Zande, Brekelmans, Vermunt, & Jan Waarlo, 2009). Younger students tend to view science with wonder and enthusiasm but, as they progress towards high school, this interest and excitement wanes or disappears. Educators need to use teaching methods that will excite and engage students in the concepts and processes of science. As the Association of Universities and Colleges in Canada (AUCC) (2011) suggests, “a high quality learning experience produces more engaged and productive students who, upon graduation, become Canada’s future thinkers, scientists, managers, leaders and innovators” (p. 5).

The literature strongly suggests that early engagement of students in their education can positively impact their decision to complete their schooling and graduate (Appleton, Christenson, & Furlong, 2008). Hampden-Thompson’s (2013) research suggests that there is a link between the type and amount of teaching and learning activities and students’ engagement in science. This relationship was studied to see if it correlates with students’ motivation and desire to pursue further studies in the field of science.

Student engagement has been an important issue in the teaching profession. The literature states that engagement is multidimensional, essential for learning, developmental in nature and malleable (Carter, Reschly, Lovelace, Appleton, & Thompson, 2012). The definition of engagement that this research will focus on is the

students' investment and effort directed toward learning and understanding the knowledge of their academic work.

Good teaching involves focusing on more than just student content learning. It encompasses all aspects of the student, from their beliefs, emotions, interests, and social skills, to their academic life. All of these components help the students prepare to move forward in their lives. As Allison Zmuda (2010) so eloquently wrote,

“[T]he mission of the 21st century learning organization, our schools, is to engage all learners in the acquisition of key knowledge and skills and the development of connections so that they can pursue powerful questions, tackle complex problems, collaborate with diverse people, imagine new possibilities and communicate their ideas.” (p. 2)

Therefore, teachers must design their classrooms and courses to allow for this acquisition.

Engagement is one of the key components to student success and future schooling. As Appleton et al. (2008) stated, “Every school irrespective of school level, geographic locale, or demographic characteristics of students has students who are disengaged and engaged” (p. 377). If we are concerned about students' success, then we must use teaching methods that engage students. We must teach them the skills to become self-directed learners.

The idea of effective teaching is characterized by learning tasks that have the features of instilling deep thinking, immersion in a problem or situation, connection to the real world, intellectual rigor and unlimited collaboration (Willms et al., 2009).

Canada needs young people who have the skills and knowledge to be successful in a

complex technologically advancing society. Educators play a significant role in preparing students for this challenge.

Preparing a student for the 21st century involves teaching analytical thinking skills that will enable him to ask penetrating questions and problem solve. These skills will be most successfully taught in an engaging environment where the student is able to apply them. One teaching method that allows for engagement of students is case studies.

In Chapter 2, I examine the available literature on engagement, critical thinking skills, Problem-based Learning, and the case study teaching methodology. I then use the literature associated with the research on case studies in teaching and learning to describe the impact of this methodology on the development of the aforementioned skills.

Chapter Two: Literature Review

Purpose of the Literature Review

In this chapter I provide an overview of the foundations upon which this research is based. I will review the literature on case studies, Problem-based Learning, engagement, and critical thinking. This is followed by the theoretical and conceptual framework that guides the research.

This overview allows for the objectives of the research to take shape. It clearly identifies where the gap in the literature exists and how that missing research frames the focus of this study. The purposes of the study and research questions are identified.

2.1 Case Studies

2.1.1 Description and Types. A case study is a story or narrative, with a pedagogical objective, that provides background information and generates questions in an attempt to motivate students to learn knowledge (White, Whitaker, Gonya, Hein, Kroening, & Lee, 2009). The characteristics of a good case study, as outlined by Herreid (1998) are that

- it tells a story,
- focuses on interesting and arousing issues,
- is current (within last five years) and relevant,
- creates empathy with the central characters,
- is pedagogical, and
- is conflict provoking and decision forcing.

There are a variety of styles of case studies. The ones most commonly identified in the literature include the interrupted case method, the intimate debate method, the directed case method and the clicker case method.

The interrupted case method, also known as progressive disclosure, involves providing students with pieces of information on an intermittent basis. The student has the opportunity to formulate ideas and make decisions that may change upon receiving additional information about the problem from the teacher. This method allows the teacher to control the pacing of the lesson (Herreid, 2013, p. 167). Problem-based Learning, which is discussed later, is an example of the interrupted case study that is much less directive in nature.

The intimate debate method involves students, in small groups of 2-4, being given information supporting one of two positions in a dilemma. The students read the arguments for one position and convey those points to the group of students studying the other position. The intimate debate ends with both sides leaving their viewpoint and joining together to reach consensus on a possible solution to the situation (Herreid, 2013, p. 182).

A third style of case study is called the directed case method. This method “is a mixture of an individual assignment and a structured whole class discussion led by the teacher” (Herreid, 2013, p. 299). The cases are stories or situations that apply the content covered in class. The students read the scenario and respond to a set of predetermined questions.

The clicker method is when a case scenario is presented to the students by way of lecture. The students may be required to discuss certain aspects of the case with their neighbors. Throughout the case scenario, selection type questions are projected by the teacher using presentation or clicker software. The students are required to answer each question using a clicker. A clicker is a handheld device with a remote sensor that each

student uses to enter a response. The responses are immediately received by the computer, tabulated and made visible as a class result. There are a variety of different types of clickers that can be used in a class. This particular case method is easy to use with large class sizes if there is accessibility to clickers. Other case types, which require small group work, are more difficult to do when accommodating a large class size.

2.1.2 Problem-based Learning. Problem-based learning is one type of case-based instructional approach. It provides students with the opportunity to identify and frame a problem using a plausible real world scenario, to review their current knowledge, to research information to add to their existing knowledge and to make decisions based on their findings. This is something that traditional lecture-based learning does not generally enable as it tends to be a more directed style of instruction that positions students as passive learners. The general procedure for Problem-based Learning involves a small group of students reading a case and identifying what they know, what they don't know, and what they need to know. The students then partition what needs to be known to solve the problem and research on their own. When they re-group, they teach each other what they have learned and attempt to solve the problem. The teacher generally acts as a facilitator focusing on maintaining good group dynamics throughout the project. Albanese and Mitchell (1993) state that "Problem-based learning at its most fundamental level is an instructional method characterized by the use of...problems as a context for students to learn problem solving skills and acquire knowledge..." (p. 53). The problems provided for instruction can be open-ended and require self-directed learning from the student (Rhem, 1998).

The instructional approach of Problem-based Learning has been used favorably in the medical field for over 40 years. McMaster University in Ontario, Canada has successfully used Problem-based Learning in its School of Medicine since 1969. In more recent years Problem-based Learning has been introduced into courses in other disciplines such as business, nursing, pharmacy and education. There is, however, limited evidence of its effectiveness in some of these professional areas. Rhem (1998) suggests that educators consider using this approach if they are interested in having their students develop critical and higher order thinking skills and work in collaborative teams to solve problems. This student-centered approach, which allows students to be self-directed in their learning, engages and requires them to use reasoning and problem solving skills. They become independent researchers while collaborating with group members. The students are responsible for their own learning, because the solution to the problem rests with them. "Learner motivation increases when responsibility for the solution to the problem and the process rests with the learner." (Savery 2006, p. 13) This approach to education lends itself to the development of reflective thinkers, who review and analyze the information gathered, as opposed to impulsive thinkers, who react without addressing adequately the information.

Gijbels, Dochy, Van den Bossche, & Segers, (2005) have identified six key characteristics of Problem-based Learning. These characteristics are as follows:

- learning is student centered,
- learning occurs in small student groups,
- a facilitator or tutor may be present,
- authentic problems are encountered at the beginning of the learning sequence before any preparation or study has occurred,

- the problems presented are used as tools to achieve the required knowledge and problem solving skills necessary to solve the problem, and
- new information is acquired through self-directed learning (p. 6).

The focus of Problem-based Learning is for students to develop and implement their problem solving skills while they are acquiring the content knowledge (Gijbels et al., 2005). In Problem-based Learning, the learner is active and required to make connections to their existing knowledge. The design of case studies requires the student to identify and frame the problem and the information needed to solve the problem, research information, make connections, draw inferences and make decisions. Active participation in the situation and application of problem solving skills are key components of carrying out a case study.

Gijbels and colleagues (2003) in their meta-analysis study discovered that there was no clear superiority of a Problem-based Learning curriculum over the traditional lecture-based teaching of the curriculum in terms of knowledge gain. However, the engagement of the students and retention of knowledge was higher with the Problem-based Learning method. This led several higher-level educational organizations to adopt a Problem-based Learning approach and offer training seminars to their staff (Savery, 2006). The research by Albanese & Mitchell (1993) found that Problem-based Learning is more nurturing and enjoyable. The students involved with Problem-based Learning generally did better on application tasks but not on test-based assessments or examinations.

Problem-based Learning, using case studies, exposes students to problems that may not have one definite solution. This forces the student to identify the gaps or missing links in their knowledge base, research that knowledge, make a decision or

develop a conclusion and use critical thinking skills to support or justify their response. Some problems integrate social issues or moral dilemmas and, therefore, can allow the student to practice making responsible decisions with justification (Carrio, Larramona, Banos, & Perez, 2011). Savin-Baden (2000) suggests that there is not necessarily a pre-determined correct answer to a problem. This means that students need to engage with the situation presented and research the knowledge and skills that will help them effectively manage it.

Engagement in learning occurs with the problem-based strategy. It is believed to inspire internal motivation in students and lead them to become life-long learners (Zenobia, 2013). Savery (2006) identifies several skills that Problem-based Learning could develop. These include “the ability to think critically, analyze and solve complex, real world problems, to find, evaluate, and use appropriate learning resources; to work cooperatively, to demonstrate effective communication skills, and to use content knowledge and intellectual skills to become continual learners” (p. 12). I believe the application of these learned skills will allow the student to become a capable citizen in the twenty-first century.

A meta-analysis conducted by Gijbel et al. (2003) found that Problem-based Learning had a powerful effect on the development of students’ skills, including performance based skills.

In order to gain the most positive benefit from Problem-based Learning, one must be aware of and address the drawbacks associated with it. Problem-based Learning requires a significant amount of time to complete a project or task as there are several steps, previously described, that the group members need to perform. Problem-based

Learning cannot necessarily control for the learning that occurs. This may make it difficult for a teacher to cover the course content. There are some solutions to these dilemmas. One could adapt the format of Problem-based Learning to align with the content but still allow for flexibility of research on the part of the student. Another possible solution would be to reform the curricular outcomes to cover more depth on fewer topics as opposed to the breadth of topics.

The assessment of Problem-based Learning is a concern. The majority of the techniques currently used for assessing follow a multiple choice format. If Problem-based Learning is being used to teach students specific skills, such as critical thinking, then the assessments should measure for those skills. Dochy et al. (2003) concluded that the more the assessment instrument is capable of evaluating the skills of the student, the larger the ascertained effect of Problem-based Learning.

In Problem-based Learning students will learn that there are situations that have no straightforward answers. As a result, they will need to look at the problem in its context and determine some viable solutions. This method is designed to be interactive and requires the participant to think, discuss and, if necessary, continue to search for more information (Herreid, 1994). This is the underlying principle of Problem-based Learning and fundamentally why it is a successful teaching strategy for engaging learners.

2.1.3 Benefits of Using Case Studies in Teaching. The intent of case studies is to provide students with an avenue to become engaged and apply their skills in an authentic situation. The focus of this teaching approach is to engage and educate the students about particular content or dilemmas that they may encounter in life. It is meant

to be thought provoking and arouse curiosity so students will become cognitively engaged and apply their prior knowledge in an authentic situation. This real-world connection will bring relevance to the content being taught and help students create the scaffolding that will allow them to remember the information.

An advantage cited for using case studies is that they include situations or problems where the student must use analytical skills to problem solve and make decisions in, at times, ambiguous or uncertain circumstances. There may not be a single correct solution to the dilemma (Boston University Center, 2013). Case studies can be used in any discipline. They are accessible from the websites of various universities, cover a wide range of topics and use different formats that allow a teacher to choose which outline best suits the educational objectives. Moreover, case studies are design friendly and easy to adapt or modify as needed.

As the American philosopher John Dewey (1938) indicated, students learn best when they can have input into their learning and relate that to previous experiences. “The case study method allows students to use their prior knowledge and interests related to the case to construct new knowledge” (Herreid, 2011, p. 29). Cases involve active participation and reflection throughout the process. Students that are actively involved in their learning use cognitive processes that stimulate critical thinking (Popil, 2011). A goal of this approach is to help students become critical thinkers so they will use those skills and learn how to ask insightful questions about topics of interest to them. Several of the case studies involve the students locating, analyzing and questioning the evidence, and looking for or constructing other plausible explanations or meanings. All of these activities are components of critical thinking.

Cases can involve working individually, in pairs or small groups, or in some instances as a whole class. Working together in small groups can help students develop interpersonal skills. Herreid (2004) states “if reading, arguing and challenging are hallmarks of critical thinking, then case studies are the poster children for the process” (p. 14). This clearly suggests that the case study teaching methodology is able to teach the students the skills necessary for critical thinking by engaging them in a problem or dilemma.

2.1.4 Research on Link between Case Studies and Students Outcomes.

Each of the case study methods is, in its own way, focused on engaging students in a situation or dilemma that requires them to work toward an outcome or solution to a problem. Rotgans, & Schmidt (2011) have found that as students’ progress through a problem-based learning situation, their cognitive engagement increases as a result of a greater feeling of autonomy. This autonomy occurs from an increase in knowledge and choice. The interrupted case method, which involves information being provided in pieces to students working in groups, lends itself to creating this sense of autonomy.

A study was done in three sections of a General Biology class, with a total of 220 students, to determine whether students felt that case studies helped them learn the content and increase their interest in the course. Eighty five percent of the students voted that case studies were useful, very useful or extremely useful in learning the content. In summary, the results showed that the “biology students became more engaged in the learning process and motivated to learn the course material” (Klein, 2000).

This method of instruction can be used at any level of education. It promotes active participation and cooperation among peers while increasing the students’ depth of

learning. Case studies have the ability to bring abstract or disparate concepts to life as they challenge students to research, analyze, draw meaning, and make inferences and/or decisions about a situation. Cases also allow the teacher to assess student understanding or misunderstanding about concepts (Herreid, 1994) and for students to revise and improve their thinking as they progress through a case. In addition, this approach to teaching and learning encourages critical dialogue among students about the claims they make based on their research into a dilemma. This dialogue can increase a student's reasoning ability and conceptual understanding about the content being studied (Chowning, Griswold, Kovarik, & Collins, 2012).

Research of the clicker method carried out by Herreid (2006) has shown class attendance to increase dramatically (up to 90% attendance). The students responded that “they value this approach over the traditional lecture” (Herreid, 2006, p. 46). The same study had overall class grades increase and showed improved performance on critical-thinking questions.

As previously mentioned, this case study approach to teaching has been prominent in the fields of law, business and medicine. A study performed in the field of nursing compared case-based instruction to traditional lecture-based instruction. The authors cite several benefits of the case-based method; however the data did not support the advantages of one method over another. The authors did state, however, that students showed interest in the case-based method of instruction (Farahani, & Heidari, 2013). In 2007, Terry performed a study with forty undergraduate students in a general science course “to examine general and domain specific critical thinking skills in college students, particularly ways in which these skills might be increased through the use of

case study method of teaching” (Terry, 2007, p.ix). The data showed that the students “experienced positive changes in general critical thinking” (Terry, 2007, p.ix). The data did not show that the case-based method was more effective than the traditional instructional method in student achieving these skills. Terry suggests that future research should be done to address the issue by utilizing a pre-test and post-test experimental design. This provides a focus for the secondary level study on critical thinking skills described in this thesis.

2.2 Engagement

2.2.1 Types of Engagement. Engagement, as defined by the Merriam Webster online dictionary, is “the state of being in gear, emotional involvement or commitment” (Merriam Webster, 2013). It is the action of being involved or committed to the task at hand. Skinner and Belmont (1993) define engagement as “sustained behavioral involvement in learning activities accompanied by positive emotional tone” (as cited in Appleton et al., 2008, p. 371).

The type of engagement that is the focus of this current research study is *cognitive* engagement. Yazzie-Mintz (2009) states that its focus is on the “students’ effort, investment and strategies for learning” (as cited in Appleton et al., 2008, p. 371). Carter and colleagues (2012) define cognitive engagement as “student’s level of investment in learning and includes aspects such as perceived relevance and challenge sufficiency of coursework, appropriate application of learning strategies, self-regulation, perceived competence, and willingness to exert necessary effort to master difficult skills” (p. 62). It involves the students’ desire to learn and to master the skills using their metacognitive strategies. For the purpose of this current research study, cognitive engagement is

defined as the effort shown by a student towards understanding the knowledge and skills being studied by asking questions, generating ideas and collaborating with peers.

The meta-construct of student engagement has been a focal point of discussion and research in the educational community for the past several years (Harris, 2011). There are four different dimensions of engagement that are addressed in the literature. These are behavioral, academic, psychological and cognitive engagement. Behavioral engagement focuses on student attendance, participation in class or participation in extracurricular activities. Academic engagement is the time spent on task in school, including work completed at home and credits earned toward a diploma at the high school level (Appleton et al., 2008, Carter et al., 2012, Harris, 2011). These two dimensions of engagement, behavioral and academic, are more frequently studied because they are easily quantifiable. Psychological engagement and cognitive engagement tend to be more abstract. Harris (2011) suggests that perhaps this is the reason psychological and cognitive engagements are far less examined in the research. Students' interest in, attitude toward, and enjoyment of school and general sense of belonging in the classroom and in school are classified as psychological engagement. The literature suggests that these three forms of engagement, behavioral, academic and psychological, determine students' "engagement in schooling," whereas cognitive engagement is "engagement in learning" (Harris, 2011, p. 377).

2.2.2 Factors that Contribute to Engagement. An individual who is cognitively engaged in his learning will demonstrate some of the following criteria as outlined by Reading (2008), Solis (2008) and Chapman (2003):

- Take responsibility for the content.
- Want to learn new applications and skills.

- Attempt to actively construct and create in the learning situation.
- Demonstrate enthusiasm, curiosity, and interest in the activity.
- Persist with difficult tasks.
- Listen, observe, and respond (immersed in task).
- Take more responsibility for their own learning (autonomy).
- Work well in group situations and independently.

Cognitive engagement is concerned with a student's commitment to learning by goal setting and using strategies to master the knowledge or coursework (Hampden-Thompson et al., 2013). If students are made aware of how they learn, what they know and don't know, and what they need to do to enhance their learning knowledge of their metacognition, this awareness will help them with goal setting.

Cognitive engagement lends itself to improvement in student learning (Harris, 2011). Students who are put in charge of their learning tend to be more interested, motivated and engaged in the process.

2.3 Critical Thinking

2.3.1 Definition of Critical Thinking. Science is an ever-progressing field of study. A scientist understands that concepts change and evolve as new discoveries occur. The American Association for the Advancement of Science states, "today's biologists require new skills to address the challenges of the 21st century, including the ability to think and contribute outside their disciplinary boundaries" (AAAS, 2011, p. 3). It is for this reason that students should be taught the skills to deal with changing information, to be able to extend their knowledge, and to learn to ask insightful questions. We are in a state of technology where access to facts is at our fingertips. It is more important than ever to teach students to think critically about the information they are accessing. The skills of a critical thinker will allow them to look for "consistencies and inconsistencies in

logic, alternative interpretations, and subtle but pervasive biases that may lead to erroneous conclusions” (Chiras, 1992, p. 464). Additionally students need to be able to identify conclusions that may not be grounded in supporting evidence. As Jeevanantham (2008) suggests, critical thinking is important as it will allow the student to carefully question the evidence provided and make a reasonable judgment on the claims or conclusions given.

According to the Foundation for Critical Thinking, there is no single correct definition of the term “critical thinking”. There are, however, several key factors incorporated in definitions that can be identified. Critical thinking is high level thinking that involves analysis, evaluation, reasonableness, reflection, self-correctiveness, and sensitivity to context. It also allows one to make judgments about the world (Jeevanantham, 2008).

Experts have determined that critical thinking falls into two domains; cognitive skills and affective dispositions (Facione, 1990). They believe that there are six central features of the cognitive skills namely: (1) interpretation, (2) analysis, (3) evaluation, (4) inference, (5) explanation, and (6) self-regulation (Facione, 1990; Facione, Facione, & Giancarlo, 2000). These six features enable cognitive processes such as refining generalizations, transferring insights to new situations, developing perspectives that lead to beliefs, arguments or theories, and then analyzing and interpreting the results of the arguments or theories (Black, 2005).

The affective disposition of critical thinking refers to the temperament or character of an individual who chooses to habitually use the above stated critical thinking skills in situations where they are applicable (Facione, 1990; Facione et al., 2000; Lee,

2013). This involves exercising fair mindedness, developing intellectual integrity, thinking independently and suspending judgment (Black, 2005). All are important life skills for students, because they will help them become responsible members of society.

There is no consensus on the most effective way to teach students the skills for critical thinking. One suggestion is to use a single course of study, as it is believed that the skills are significant enough that they need to be taught in isolation of the content of disciplines. A concern with this approach is that critical thinking skills are not necessarily readily transferable from one context to another and, therefore, students may not be able to adapt and use the skills in specific discipline areas.

Another opinion takes into account the fact that the skills used for critical thinking are applicable to all areas of life and learning and, as such, should be taught in discipline specific courses using appropriate teaching methodologies (Facione, 1990). This approach has the students practicing the skills as they learn or apply content knowledge. This current research study involved teaching the students these skills through a subject specific course.

Facione (1990) has outlined the following list of critical thinking skills and sub-skills (Table 1). As presented, they are comparable with the highest levels of Bloom’s Taxonomy (as stated prior to 2001).

Table 1
Critical Thinking Skills Comparison Chart

Consensus List of Critical Thinking Skills and Sub-Skills		Bloom’s Taxonomy Critical Thinking Skills	
Skill from Facione	Sub-Skill	Bloom’s Taxonomy	Skill
Interpretation	Categorization, decoding significance, clarifying meaning	Synthesis	Making connections, constructing or drawing meanings , hypothesizing, formulating ideas
Analysis	Examining ideas,	Analysis	Examining facts,

	identifying arguments, analyzing arguments		Identifying aspects of problem, reflective decision making
Self-regulation	Self-examination, self- correction		
Evaluation	Assessing claims, assessing arguments	Evaluation	Assessing and critiquing quality of information, Examining evidence for logical consistencies,
Inference	Querying evidence, conjecturing alternatives, drawing conclusions		
Explanation	Stating results, justifying procedures, presenting arguments		

The three highest categories in Bloom's Taxonomy all require higher order thinking and interpretation. The synthesis level correlates to the interpretation section of Facione's skill set as both involve making connections and clarifying ideas. Bloom's analysis level, which includes examining, decision making and reflection, is synonymous with Facione's analysis and self-regulation. The final level, evaluation, of Bloom's taxonomy is similar to the evaluation, inference and explanation section of Facione's design of critical thinking skills.

2.3.2 Factors that Contribute to Students' Critical Thinking Development.

There are several phases that have been identified in the process of becoming a critical thinker. S.L. Edwards (2006) outlined a framework to "promote and engage nurses in the concepts of critical thinking" (p. 303). Chiras (1992) produced an outline of principles of critical thinking. The framework and outline of principles designed by these two researchers overlap on several key ideas. Both involve teaching the students how to systematically gather sufficient information for identification of the problem or situation, how to look for and acknowledge hidden assumptions and biases, how to consider all

viewpoints in order to make connections or to see the big picture, and how to continually ask questions that lead to a clarification of facts before making any decisions. Once a decision is made, if it is possible to make a single decision, students need to clearly justify their reasoning and be accountable for their decision. The last phase requires a re-evaluation and reflection on the result (Edwards, 2006; Chiras, 1992). These are the cornerstones of becoming a critical thinker. If “the skills of critical thinking and argument are an essential part or aspect of education for citizenship” then it follows that this process of teaching critical thinking skills is necessary (Costello, 1996, p. 48). Such skills provide the tools needed to function as a successful citizen in this rapidly changing world.

2.4 Purpose of Study

The purpose of this study is to determine the effect of case study instructional methodology on the promotion of students’ critical thinking and cognitive engagement in a Grade 12 biology unit called Evolutionary Theory and Biodiversity. This study involves using case studies, which are authentic scenarios, to teach the curricular content in the biology unit.

In twenty-first century classrooms there exists a diverse group of students with a variety of learning styles, educational needs and personal issues that affect learning. In order to meet the learning needs of these students, teachers are required to use a variety of teaching strategies. Case study methodology is one teaching strategy that appeals to the exploratory type of student who learns by discovery. This method incorporates research, problem solving, analysis, decision making, and collaboration. Case studies

give the students a comprehensive view of an authentic situation and can be developed to engage all students no matter their learning style.

A review of the literature has shown that the majority of work with case study methodology used as a teaching approach has occurred in the fields of medicine, law and business. Although research has been performed using this method with secondary school students, the focus was on academic achievement, problem solving skills, teamwork skills, and science attitudes. This study fills the gap that currently exists in the science education literature by focusing on student's learning, cognitive engagement and critical thinking skills in high school biology classes where a case study teaching approach is implemented.

2.5 Research Questions

The research questions this study is focused on are as follows:

1. Do students exposed to a program using a case study teaching methodology demonstrate greater cognitive engagement than those taught with the traditional lecture style instructional approach?
2. What are the benefits and drawbacks of the case study teaching methodology on student learning?
3. In what way does the case study teaching methodology affect students' use of critical thinking skills compared with students taught with a traditional lecture style instructional approach?

The answers to these questions should provide insight into the effectiveness of this teaching methodology on student engagement of learning and the development of

critical thinking. The case study approach was used to determine if this is a worthwhile strategy to use for teaching students in high school biology.

2.6 Theoretical and Conceptual Framework

The case study instructional methodology is informed by a social constructivist theory of learning. As such, it incorporates the assessment of prior knowledge so planning for learning begins with the knowledge of the students. It also actively involves students in relevant authentic problems where they have an opportunity to collaborate, explore and reflect on their ideas (Skolnick, 2009). The goal is to guide students to become self-directed learners in a community of inquiry where they will actively integrate new scientific knowledge with their existing knowledge and formulate insightful questions to guide further learning.

The conceptual framework illustrated in *Figure 1* below shows the connections between the variables that were being studied. It identifies the suggested links between each of these concepts.

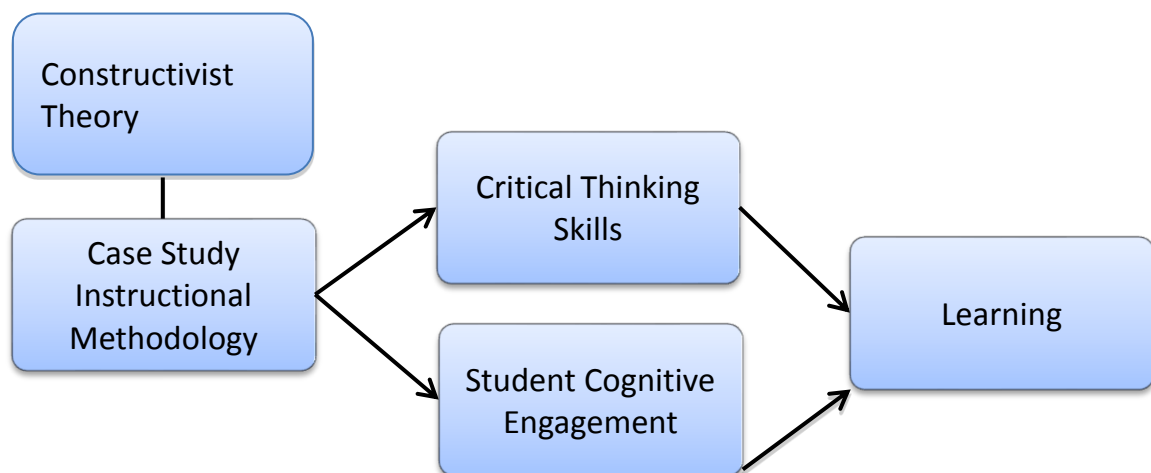


Figure 1: Conceptual Framework for Research Study

The independent variable is the instructional strategy that will take on the value of either traditional lecture or case study. The intermediate variables are the development of critical thinking skills and student cognitive engagement. The dependent variable is student learning.

The instructional goal of this study is to teach students that science is more than acquiring the knowledge provided by scientists. It is about asking insightful questions, critiquing ideas, wondering/pondering about possibilities, hypothesizing and moving forward in the development of a deeper understanding of the world in the 21st century. This is the process of science and the means by which students can become scientifically literate citizens.

The literature that framed the purpose of this study has been reviewed in Chapter Two. In Chapter Three, I will outline the research methodology by identifying the participants, case studies used, data collection techniques and the measurement tools used for critical thinking, engagement and learning.

Chapter 3: Research Methodology

This study followed a mixed method research design. This approach was chosen because it provided more specific and detailed information pertaining to the research questions. More specifically, a triangulation mixed method design was used. This design involves collecting both qualitative and quantitative data, analyzing this data, and drawing conclusions that enable the research questions to be answered.

The teacher-researcher taught the first half of the unit using case-based instruction, while her colleague taught the first half of the unit using traditional lecture-based instruction. This was switched for the second half of the unit, with the colleague's class experiencing case-based instruction and the teacher-researcher's class the traditional lecture-based method. Thus, this research is an example of 2X2 factorial design with four conditions. There are two factors in this experimental research, which are setting and type of instructional method. The setting has two levels in itself, the students in Class 1 taught by the colleague and the students in Class 2 taught by the teacher-researcher. The instructional method also has two levels, these levels being case study and lecture-based instruction.

3.1 Participants

3.1.1 Staff Participants. This study involved a teacher-researcher, a participating biology teacher (referred to as "the colleague"), and a third party individual.

The third party individual was necessary for the purpose of explaining the research study to the students and presenting to them the option to participate or not participate in the study (see Appendix A1 and Appendix A2). The individual provided consent forms to the students and parents of participating students (see Appendices B1 to

B4), and collected and stored data from the study that the teacher-researcher could not have access to until the course had ended and the students had received their final grades in the course. The third party individual was selected based on the fact that he had no power over relationship with any of the students in the two biology classes (see Appendix C1 and Appendix C2). This eliminated any pressure the students might have felt to participate or any concern about repercussions if they decided not to participate. The third party individual signed an Oath of Confidentiality as part of his participation in the study (see Appendix C3).

The biology teacher that participated in this research study has been a colleague of the teacher-researcher for 9 years. He has collaborated with the teacher-researcher on several projects, and they are members of the Science Professional Learning Community in their school. A consent form was signed by the participating biology teacher to indicate his acceptance of the role and its responsibilities (see Appendix D1 and Appendix D2). The colleague's responsibilities included teaching the unit of biology, administering the pre-test and post-test on critical thinking (see Appendix E), performing direct observations of small groups (see Appendix F), and administering and assessing two assignments (see Appendix G1 and Appendix G2) and one unit test (see Appendix G3) for the students in his class (Class 1). The colleague regularly collaborated on the progression of the lessons and the data collected.

The proposal defense for this research study occurred in January 2014. Immediately following the successful defense, the process for ethics approval began. The Education and Nursing Research Ethics Board (ENREB) approved the study in April 2014, at which time the Superintendent of the school division and principal of the high

school signed their informed consent forms indicating their acknowledgement of the research study (see Appendix H, H1 and Appendix H2). The third party presented the study to the participants in May 2014, at which time the letters of assent went out to the parents explaining the study's purpose. Implementation of the study and data collection began in mid-May 2014 in both biology classes. The analysis of the data, conclusions and discussion occurred over the course of two months (July and August 2014) with a defense of the thesis in December 2014.

3.1.2 Student Participants. Participants for the study were approximately 40 male and female students, 17 to 18 years of age who were enrolled in two sections of a grade 12 biology course at a rural school located in south-central Manitoba. The school has approximately 600 students in grades 9 to 12. The majority of the students were Caucasian and of middle class backgrounds.

The course was taught in a laboratory setting that is furnished with large desks to facilitate group work. There was adequate space in the classroom for groups of 3-5 students to have their own work-station and conduct research on computers as they found necessary.

Both biology classes were scheduled from Monday to Friday and were 65 minutes in duration. The study was conducted in a period of one month and occurred in a total of 36 classes (18 per section of the course). The duration of each type of teaching methodology in each class is outlined in Table 2.

As mentioned, there were two classes of grade 12 biology students participating in the study. One class was taught by the teacher-researcher and the other class was taught by a colleague. The same content from the 2011 *Grade 12 Biology: Foundations*

for Implementation document from Manitoba Education Unit 3 was taught and identical assessment methods were used throughout the study. The unit of study sequence and plans for the 18 lessons were developed collaboratively by the teacher-researcher and her colleague. To elaborate on the design of the study (as shown in Table 2), the teacher-researcher taught the first half of the unit, meeting the curricular outcomes, using case studies. She taught the second half of the unit using the traditional lecture-based method. The participating biology teacher did the reverse of this. He taught the first half of the unit using the traditional lecture-based method and the second half of the unit using case studies. The purpose of this technique was to allow for a control (traditional teaching method) and experimental portion (case study teaching method) for each class to counterbalance for the different teachers and teaching methodology.

Table 2
Study Outline for Each Class

Unit of Study	Curricular Outcomes	Control Group (Lecture-based teaching)	Experimental Group (Case study teaching)
Unit 3: Evolutionary Theory and Biodiversity	SLO (B12-3-01 to B12-3-07)	Participating Biology Teacher (11 of 18 classes)	Teacher-Researcher (7 of 18 classes)
	SLO (B12-3-08 to B12-3-12)	Teacher-Researcher (10 of 18 classes)	Participating Biology Teacher (6 of 18 classes)

3.2 Measures

The matrix below (Table 3) illustrates how the data collection techniques fit with each research question.

Table 3
Matrix of Data Collection Techniques

Research Question	Type of Method of Data Collection	Interview/Observations	Artifacts/Products	Numerical Data
Do students exposed to the case study teaching methodology demonstrate greater cognitive engagement than those taught with the traditional lecture style	Quantitative/ Qualitative	Observations of interactions (field notes); Semi-structured interview/ questionnaire		

instructional approach? What are the benefits and drawbacks of the case study teaching methodology on student learning?	Quantitative	Assignment on Unit Content with Rubric; Final Unit Test	
In what ways does the case study teaching methodology affect students' use of critical thinking skills compared with students taught with a traditional lecture style instructional approach?	Quantitative		Pre-test and Post-test of Critical Thinking Skills with Rubric

As presented in Table 3 the following forms of data collection techniques were used for this research study: pre-test and post-test on critical thinking skills, two student work samples, direct observations on cognitive engagement, a semi-structured interview/questionnaire with participants on engagement, and a unit test.

3.2.1 Case Studies. There were six different case studies used throughout the course of this research. The case studies were from the National Center for Case Study Teaching in Science (NCCSTS). Each class was given three case studies during the case-based teaching section of the unit. The types of cases used were a mixture of Problem-based Learning, role playing, jigsaw, dilemma/decision, interrupted cases and clicker cases. Table 4 outlines the case name, case type and the duration of the lesson that was made available in each class.

Table 4
Case Studies Used In Research

Class	Case Name	Type of Case Study	Length of Case
Class 1 (Colleague)	PKU Carriers: How many are in your hometown?	Interrupted	2 classes
	A Sickeningly Sweet Boy	Interrupted, Dilemma/Decision	2 classes
	As the Worm Turns (Speciation and the Apple Maggot) combined with "What is a Species"	Interrupted, Dilemma/Decision	2 classes
Class 2 (Teacher-	The Galapagos	Problem-based Learning, Role play, Jigsaw, Dilemma/Decision	4 classes

researcher)	I'm Looking Over a White Striped Clover	Interrupted	2 classes
	Cross-Dressing Salmon (Survival of the Sneaky)	Clicker/Interrupted	1 class

The study included 18 classes, 17 of instruction or guided/self-directed activity and one class for students to write the unit test. In Class 1, the colleague's class, 6 of the 17 classes were spent on case-based instruction, while in Class 2, the teacher-researcher's class, 7 of 17 classes were spent on case-based instruction.

During the case-based instructional time, students were put into small groups of three to four by the teacher and provided with the case study that corresponded to the outcomes they were learning. Each case was designed to fit with specific outcomes in the unit of study, as presented in the 2011 *Grade 12 Biology: Foundations for Implementation* document from Manitoba Education. Table 5 outlines each case and the specific learning outcomes covered.

Table 5
The Case Studies and The Specific Learning Outcomes

Case Name	Specific Learning Outcomes
PKU Carriers: How many are in your hometown?	B12-03-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. B12-03-09: Discuss how genetic variation in a gene pool can be altered.
A Sickeningly Sweet Boy	B12-03-09: Discuss how genetic variation in a gene pool can be altered. B12-03-10: Describe how populations can become reproductively isolated
As the Worm Turns (Speciation and the Apple Maggot) combined with What is a Species	B12-03-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. B12-03-10: Describe how populations can become reproductively isolated B12-03-11: With the use of examples. Differentiate between convergent and divergent evolution (adaptive radiation).
The Galapagos	B12-3-01: Define the term evolution , explaining how evolution has led to biodiversity by altering populations and not individuals B12-3-02: Describe and explain the process of discovery that led

	Charles Darwin to formulate his theory of evolution by natural selection. B12-03-03: Outline the main points of Darwin's theory of evolution by natural selection.
I'm Looking Over a White Striped Clover	B12-03-04: Demonstrate, through examples, what the term survival of the fittest means in the phrase "survival of the fittest." B12-03-05: Explain how natural selection leads to changes in populations. B12-03-06: Describe how disruptive, stabilizing, and directional natural selection act on variation.
Cross-Dressing Salmon (Survival of the Sneaky)	B12-03-04: Demonstrate, through examples, what the term survival of the fittest means in the phrase "survival of the fittest." B12-03-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. B12-03-07: Distinguish between natural and artificial selection

Three of the cases used were slightly modified in some form to meet these outcomes. The cases modified were "PKU Carriers", "A Sickeningly Sweet Boy" and "As the Worm Turns." These needed modification for either content, clarity or age level appropriateness [secondary level versus post-secondary level]. The modifications were developed collaboratively by the teacher-researcher and her colleague. An example of a modification is the addition of questions in the PKU case to aid the student in understanding certain content and allow them to make the calculations using the Hardy-Weinberg equation as this was the first time they would encounter that topic.

3.2.2 Engagement.

3.2.2.1 Observations. Direct observations of the small groups of students occurred during the lecture-based lessons and case-based lessons. These observations were recorded by the teacher responsible for instruction. That is, the teacher-researcher did not observe the students in her colleague's class as he taught the biology unit, and the colleague did not observe the students of the teacher-researcher.

Observations occurred on four separate occasions for each class; twice for each type of teaching methodology. A checklist consisting of 14 different criteria formed the focus of the observations (see Appendix F). The 14 different criteria were categorized into one of three key areas: asking questions, working with ideas, or collaborating as these were components of the definition of cognitive engagement used for this research study. The division of criterion into the three categories is presented in Table 6.

Table 6
Three Categories of Engagement Observations

Category	Criteria
Asking Questions	Asking questions
	Answering questions
	Asking for help or clarification
	Trying to problem solve
	Engaging in inquiry
Working with Ideas	Generating ideas
	Connecting ideas
	Sharing ideas with classmates
	Articulating ideas to classmates
Collaborating	Interacting with classmates
	Engaged in discussion with classmates
	Working collaboratively

Each criterion was rated on a five point scale from 0-4. The teacher-researcher and her colleague discussed the specific observation criteria and the meaning of each measure. The scoring of 0 indicated a criterion that was not observed. A score of 4 indicated a criterion that was observed regularly.

The observations were carried out while the students were involved in the activity of a lesson. They consisted of monitoring each group for 4-5 minutes as the group members participated in the lesson's activity or task. Upon completion of the each set of observations, the teacher-researcher and colleague discussed the results and cross referenced their findings. The focus was on engagement of learning. These observations

were carried out to provide additional evidence about each student's engagement level in the class. The findings were compared to the questionnaire responses from the students.

Each group's scores, in Class 1, the colleague's class, and Class 2, the teacher-researcher's class, were averaged for both the lecture-based observations and the case-based observations. A paired sample t-test was conducted for each class to compare their group scores for each of the three categories.

3.2.2.2 Questionnaire/Interview. The purpose of the questionnaire and semi-structured interview was to enable students to provide their view of cognitive engagement in their learning. The students were given the questionnaire (see Appendix J) during the latter part of the unit and had sufficient class time to complete it. The teacher-researcher reviewed the responses and spoke with students when clarification was needed. The questions were designed to determine the students' perspectives on cognitive engagement in the classroom.

The responses were transcribed by the teacher-researcher. Once transcribed, the data was coded by identifying common ideas. These ideas were expressed and repeated by several participants. This analysis was done by hand to allow the researcher to become familiar with the data. The teacher-researcher grouped common codes together and identified any outliers; from here themes or categories emerged. These themes formed the main ideas in the data and allowed for findings to be explained in summary statements.

3.2.3 Critical Thinking. The Applied Critical Thinking Measure was the instrument tool used to measure the change in the students' critical thinking skills. The ACTM was designed and previously implemented by Dr. Robert Renaud a quantitative

research specialist at the University of Manitoba. This tool includes a pre-test and post-test of which each test is composed of five separate scenarios that most high school students would be familiar with. The pre-test was given to both classes at the start of the study, prior to any treatment of teaching methodology (see Appendix E1). The pre-test was evaluated using a rubric (see Appendix E2). The grading scheme of the rubric is such that the greater the demonstration of critical thinking skills the higher the score. The critical thinking skills were shown by identifying the objective of the scenario and drawing upon existing information or stating the new information necessary to make an informed decision. The post-test was given at the completion of the unit by both the teacher-researcher and her colleague. At this point in the study both classes had been taught with the case-based instructional method and the lecture-based instructional method.

The pre-test responses were analyzed to determine if there was a difference in the students' critical thinking skills between the two classes prior to the commencement of the study. A paired sample t-test was performed on the pre-test and post-test scores for each of the two classes, from the individual student scores, to determine if there was a significant difference in the critical thinking scores over the duration of the unit of study.

3.2.4 Learning. Three artifacts of student work were collected and evaluated at different times during the unit. These artifacts were constructed by the teacher-researcher and her colleague. The artifacts, which consisted of two assignments (see Appendix G1 and Appendix G2) and one unit test (see Appendix G3) were completed by each student and were included as part of the final unit grade.

The first sample was collected upon completion of the case study lessons with the teacher-researcher's class. At this point the colleague's class had completed the lecture-based lessons. Assignment 1 was given to both classes. The second assignment was completed when the teacher-researcher's class finished the lecture-based lessons and the colleague's class had completed the case-based lessons. The third and final artifact, which was the unit test, was completed by both classes at the conclusion of the unit.

The two assignments were assessed following a rubric guideline (see Appendix I) that focused on the use of higher cognitive strategies to answer the questions or solve the problems (Chapman, 2003). The unit test was assessed following an answer key designed by the teacher-researcher and her colleague.

The purpose of the study was to determine if the case study instructional methodology improves student's learning, critical thinking, and cognitive engagement. The qualitative and quantitative research methods utilized were developed to determine if this instructional strategy should be used on a regular basis in the teaching of the Grade 12 Biology course. If the results were found to support the implementation of a new educational practice [case study instruction] it was considered likely that a new plan of action on the part of the teacher-researcher and her colleague in teaching science would be developed for teaching science.

3.3 Validity/Research Quality

Guba states that there are four criteria that must be met to ensure validity of a qualitative inquiry. They are credibility, transferability, dependability, and confirmability (Mills, 2007).

Guba refers to credibility as “the researchers’ ability to take into account the complexities that present themselves in a study and to deal with patterns that are not easily explained” (Mills, 2007). The multiple forms of data collection obtained in this study lend to its credibility. The timeline for this project was over the course of one unit. This allowed for several different forms of data to be collected. The direct observations were taken to identify qualities that the participants demonstrated with respect to cognitive engagement. They supported the questionnaire results from the students. The data techniques used were critically discussed by the teacher-researcher and her colleague prior to analysis.

This study occurred in the context of a grade 12 biology class, following the government outlined curriculum. This enables transferability within that setting.

To meet Guba’s criteria of dependability, which is the stability of the data, this study used overlap methods and an audit trail. The questionnaire was designed to strengthen or refute the observation criteria. A field journal was used and included notes about the process of the study. The format of the study, which involved a crossover of the teaching methodologies between the two classes would allow for dependability of the data collected.

The final criteria deals with the objectivity of the data that is collected (Mill, 2007). Data triangulation occurred for the purpose of cross checking the findings. Artifacts, observations and questionnaire results were collected and statistical analysis was performed on the data.

The two Grade 12 biology classes that participated in the study were exposed to the same content, and received both instructional teaching methods over the same period

of time. The fact that both classes experienced lecture-based and case-based teaching methodologies counter-balanced the different teachers, experimental conditions and differences that might arise by chance between the two class participants. This latter factor could be particularly relevant in a small class where group dynamics can impact the environment of a class. The 2X2 factorial design also provides reproducibility. The statistical analysis that was performed on the data collected from the artifacts compared the results between the two classes. However, the data analysis of the critical thinking results was performed on each class individually. There were no cross class comparisons because they experienced both teaching methodologies before the post-test was administered. The conclusions drawn are therefore based on the paired sample t-test for each class.

Chapter 4: Data Results and Analysis

The primary focus of this study was to compare a new teaching methodology (case study teaching) with traditional lecture-based instruction. The effect of these teaching methodologies was determined by examining student learning, the development of critical thinking skills, and cognitive engagement. Data was collected from two different grade 12 biology classes over one unit of study, Unit 3: Evolutionary Theory and Biodiversity, in a single semester.

The research followed a 2X2 factorial design with four conditions. The two main factors were setting and type of instructional method. The setting has two levels which were the two Grade 12 biology classes and the instructional methods were case study and lecture-based instruction.

Student Demographics

There were a total of 39 students in the two Grade 12 biology classes. Twenty-five students were in Class 1, and fourteen were in Class 2. The sorting of the students into Class 1 and Class 2 was not under the control of the teacher-researcher or her colleague. Personnel in the school's administrative office registered students in a class using a computerized program. As such, the students did not select the biology class they were in. However, their choice of other course offerings impacted their placement. The demographic data of the students is described in Table 7 below.

Table 7
Demographic Data for Student Participants

Class	Grade Level		Age	
	Mean	Standard Deviation	Mean	Standard Deviation
Class 1 (Colleague)	11.76	0.43589	17.52	0.50990
Class 2 (Teacher-researcher)	11.57	0.51355	17.43	0.51355

An independent sample t-test was performed on the critical thinking pre-test scores for each class. The purpose of the t-test was to determine if there was a significant difference, prior to the study beginning, between the two classes for critical thinking skills. The results for the t-test are shown in Table 8.

Table 8

Two Sample T-Test on Pre-test Critical Thinking Scores (Class 1 vs Class 2)

Class	N	Mean	Standard Deviation	T-Value	P-Value
Class 1 (Colleague)	21	15.86	6.26	0.24	0.816
Class 2 (Teacher-researcher)	12	16.58	9.54		

Note. N refers to the number of participants in each class
* $p < 0.05$

The results of the t-test indicate that there is no significant difference between the two classes for critical thinking skills, ($t(32) = 0.24, p = 0.816$). The two classes were not randomly selected, as their choice of other courses impacted their placement in one of the two biology classes. The pre-test scores indicate that there was no selection bias as the groups are similar with respect to their current level of critical thinking skills.

Artifacts for Student Learning

This section of the analysis will show inferential statistics for the results of the two artifacts (assignments) and the unit test given at the conclusion of the biology unit. The inferential statistics used involved independent paired sample t-tests as the data consisted of two groups and a single variable of interest each time it was analyzed.

The two assignments were developed by the teacher-researcher in collaboration with her colleague. They were designed to measure student learning of the curricular content that was covered during a specific portion of the unit of study. Each individual assignment was composed of four short answer questions (see Appendix G1 and

Appendix G2) and designed to be completed within one 65 minute class period. Student work samples and mark allocations are shown in Appendix G3. Two-sample independent t-test for Assignment 1 are outlined in Table 9. This assignment was given to the students after the teacher-researcher’s class (Class 2) completed their case-study teaching methodology. Class 1 had completed the lessons addressing the identical learning outcomes using a lecture-based teaching methodology.

Table 9
Two Sample T-Test for Assignment 1 and Assignment 2(Class 1 vs Class 2)

Class	N	Mean (maximum score of 13) (%)	Standard Deviation	T-value	P-value	Degrees of Freedom
Assignment 1						
Class 1 (Colleague) <i>Lecture-based teaching</i>	25	8.26 (63.5%)	2.44	3.30	*0.002	35
Class 2 (Teacher- researcher) <i>Case-based teaching</i>	14	10.43 (80.2%)	1.65			
Assignment 2						
Class 1 (Colleague) <i>Case-based teaching</i>	25	19.96 (76.8%)	3.85	1.43	0.164	28
Class 2 (Teacher- researcher) <i>Lecture-based teaching</i>	14	21.75 (83.7%)	3.70			
Note. N refers to the number of participants in each class						
* $p < 0.05$						

The results for Assignment 1 show Class 1 having a mean score that is 16.7% less than Class 2. Assignment 1 was given when Class 1 finished lecture-based teaching and

Class 2 finished case-based teaching. This indicates that Class 2 did significantly better on Assignment 1.

Independent sample t-tests were conducted to compare the mean scores for Class 1 and Class 2 on the assignment. An alpha level of 0.05 was used. It was a two-tail test with different groups and unequal variances. There was a significant difference found between the classes on their mean scores for Assignment 1, ($t(35) = 3.30, p = 0.002$).

The second assignment was given at the conclusion of the second half of the unit. These lessons were taught using a case-based teaching approach for Class 1 and a lecture-based approach for Class 2. Table 9 shows the results for Assignment 2.

On Assignment 2, Class 1 had a mean score 6.9% lower than Class 2. This assignment was given when Class 1 finished case-based teaching and Class 2 finished lecture-based teaching. This indicates that Class 2 had scores that were higher on Assignment 2.

An independent sample t-test was conducted and it indicated that even though the mean score for Class 2 was higher than Class 1 on this assignment, the difference was not significant, ($t(28) = 1.43, p = 0.164$).

The final artifact collected was the unit test. This test was created by the teacher-researcher in collaboration with her colleague. It consisted of questions addressing all topics covered in the unit (see Appendix G4). The maximum score on the test was 44 marks. Table 10 outlines the data results obtained from the unit test for Class 1 and Class 2.

Table 10
Two Sample T-Test on the Unit Test (Class 1 vs Class 2)

Class	N	Mean (maximum score of 44) (%)	Standard Deviation	T-value	P –value	Degrees of Freedom
Class 1 (Colleague) <i>Both types of teaching</i>	24	33.54 (76.2%)	5.58	0.08	0.937	19
Class 2 (Teacher- researcher) <i>Both types of teaching</i>	14	33.75 (76.7%)	8.75			

Note. N refers to the number of participants in each class
* $p < 0.05$

There was no significant difference between the two classes regarding the mean score on the unit test, ($t(19) = 0.08, p = 0.937$). The class size for Class 1 was 24 as one student did not write the unit test.

Applied Critical Thinking Measure

The two classes are analyzed separately with respect to the Applied Critical Thinking Measure because of the design setting of the research study. Individual results are analyzed as opposed to class aggregate scores because each class wrote the post-test after being taught with both styles of teaching methodologies. This prevents cross-class comparison but does allow for analysis as to the development of critical thinking skills in each individual class.

Table 11 displays the pre-test, post-test and net-difference scores for Class 1. The mean net-difference score was 3 points with a standard deviation of 7.91.

Table 11
Critical Thinking Applied Measurement Tool - Pre-test, Post-test , and Net Difference Scores for Class 1

Student	Class 1 (Colleagues class)		
	Pre-Test	Post-Test	Net-Difference Score
1	15	8	-7
2	23	27	4
3	7	10	3
4	33	27	-6
5	14	10	-4
6	12	25	13
7	16	14	-2
8	18	14	-4
9	11	10	-1
10	13	6	-7
11	23	38	15
12	17	26	9
13	10	22	12
14	7	12	5
15	20	18	-2
16	18	28	10
17	13	18	5
18	21	42	21
19	20	17	-3
20	14	12	-2
21	8	12	4
Mean Score	3		
Standard Deviation	7.91		
T-Value	1.74		
P-Value	0.097		
Note. * $p < 0.05$			

A paired sample t-test was performed on the Applied Critical Thinking Measure pre-test and post-test scores for Class 1. An alpha level of 0.05 was used and a 95% confidence interval for mean difference. The mean score indicates that there is an improvement of 3 points on average from the pre-test to the post-test. However, the t-test

results indicate that there is not a statistically significant difference between the mean scores from the pre-test to the post-test for Class 1, ($t(20) = 1.74, p = 0.097$).

Table 12 displays the pre-test, post-test and net-difference scores for Class 2. The mean net-difference score was 7.25 points with a standard deviation of 11.10.

Table 12
Critical Thinking Applied Measurement Tool - Pre-test, Post-test , and Net Difference Scores for Class 2

Student	Class 2 (Teacher-Researchers Class)		
	Pre-Test	Post-Test	Net-Difference Score
1	18	27	9
2	10	26	16
3	8	19	11
4	21	25	4
5	11	23	12
6	23	23	0
7	8	24	16
8	13	29	16
9	6	20	14
10	28	8	-20
11	38	32	-6
12	15	30	15
Mean Score			7.25
Standard Deviation			11.10
T-Value			2.26
P-Value			*0.045
Note. * $p < 0.05$			

A paired sample t-test was performed on the Applied Critical Thinking Measure pre-test and post-test scores for Class 2. An alpha level of 0.05 was used and a 95% confidence interval for mean difference. The mean score indicates that there is an improvement of 7.25 points on average from the pre-test to the post-test. The t-test

results indicate that there is a statistically significant difference between the mean scores for students from the pre-test to the post-test for Class 2, ($t(11) = 2.26, p = 0.045$).

Table 13 provides information on each of the five individual critical thinking scenarios (see Appendix E1) that were tested with the Applied Critical Thinking Measure (ACTM) for Class 1 and Class 2 respectively. The mean scores for each scenario are given.

Table 13
Class 1 and 2 Mean Scores for Each Scenario on ACTM

Scenarios	Pre-Test Mean	Post-Test Mean	Pre-Test Mean	Post-Test Mean
	Score	Score	Score	Score
	Class 1	Class 1	Class 2	Class 2
1	3.52	3.57	5.07	3.75
2	3.68	3.14	3.00	4.67
3	2.56	3.47	3.42	3.83
4	2.24	4.43	1.93	6.75
5	3.20	4.23	2.93	4.83
Mean Score	3.04	3.77	3.27	4.77
Standard Deviation	0.62	0.55	1.15	1.21
	T-Value = 1.57	P-Value = 0.191	T-Value = 1.48	P-Value = 0.212

Note. * $p < 0.05$

A paired sample t-test was performed on the mean pre-test and post-test scores for each of the individual five scenarios of the Applied Critical Thinking Measure (ACTM). The results show that there is no significant difference between the mean scores for Class 1, ($t(4) = 1.57, p = 0.191$).

A paired sample t-test was performed on the mean pre-test and post-test scores for each of the individual five scenarios of the Applied Critical Thinking Measure (ACTM). The results show that there is no significant difference between the mean scores for Class 2, ($t(4) = 1.48, p = 0.212$).

Direct Observations and Questionnaire for Cognitive Engagement

During the course of the unit, students were given a questionnaire that required a response to three questions about engagement. Below is *Figure 2* which illustrates the connection of the common themes that emerged from students’ views on engagement.

Figure 2. Map of Common Themes of Students Views on Engagement

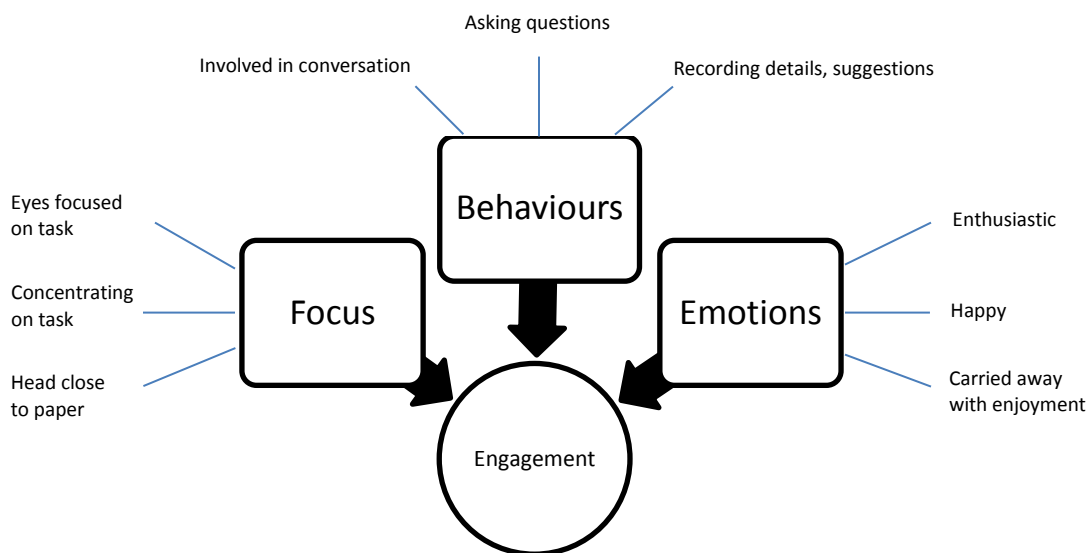


Table 14 summarizes the phrases the students used in the questionnaire.

The purpose of this questionnaire was to provide insight to the teacher-researcher as to what the students believed they would look like when engaged in learning. This information was used to corroborate direct observations that were made throughout the unit of study.

Table 14
Class 1 and Class 2 Students view on “what engagement looks like”

Focus	Eyes focused on task, not distracted or looking around Concentrating on task/topic/question/discussion Head close to paper
Behaviours (Participation)	Quiet and listening to others talk Involved in conversation Asking questions/making comments Giving answers (responses)/opinions/providing input/personal views Writing/going over details or questions/recording information Being efficient on task (Take on role of leader/delegate)
Emotions	Enthusiastic

	Having fun (happy)/good mood
	Going past allocated time for task (lose track of time)
Students	Listen and pay more attention
comments on	Better posture
<i>“how an</i>	Become more willing to speak and participate in discussion (talk about the
<i>engaging activity</i>	topic)
<i>changes their</i>	Give better and more in-depth responses (more thought on topic)
<i>actions in class”</i>	Make connections with other topics
	Work harder/faster/more efficient/put in more time on task
	Get excited/pumped up/jump in and have more energy

Classroom observations made by the classroom teacher (the teacher-researcher and her colleague) of the students occurred during the case-based teaching methodology and lecture-based teaching in Class 1 and in Class 2. This was done using an observational checklist on engagement with 14 different criteria. The criteria were then categorized into one of three key areas: asking questions, working with ideas, or collaborating, as this was the definition of cognitive engagement used for this research study. Each group's scores, in Class 1 and Class 2, were averaged for both the lecture-based observations and the case-based observations. A paired sample t-test was conducted for each individual class to compare their group scores for each of the three categories. The scores used in the paired sample t-test fulfill the requirements for being match pairs for each student in the class and having minimal outlier data. The data were collected on a continuous level, but the data does not follow a normal distribution as the sample size is very small. This does violate one of the four assumptions of a paired sample t-test procedure. However, the data obtained from the test can be used to identify patterns that exist with each class.

The observations were recorded using a five point scale from 0 to 4. A scale value of 0 indicates the criterion was not observed, 1 occurred minimally, 2 to some

extent, 3 often and 4 occurred regularly. A summary of the results for each key category is presented below in Tables 15, 16, and 17.

Table 15
Class 1 Observational Data Mean Scores for Each Group in the ‘Asking Questions’ Category

Groups	Asking Questions		
	Lecture-based	Case-based	Differences
G1	11	12	1
G2	9	12	3
G3	9	12	3
G4	10	13	3
G5	10	14	4
G6	11	11	0
Mean Scores	10.000	12.333	2.333
Standard Deviation	0.894	1.032	1.505
T-Value = 3.80		P-Value = *0.013	
Note. * $p < 0.05$			

A paired sample t-test was performed on the mean scores for the lecture-based observations and case-based observations involving the criteria that dealt with ‘asking questions’. This was done to determine if there was a statistically significant mean difference in ‘asking questions’ from a lecture-based activity to a case-based activity. Students’ mean scores were higher after the case-based instruction (12.33 ± 1.03 points) than in the lecture-based instruction (10 ± 0.89 points). This is a statistically significant mean increase of 2.33 in terms of ‘asking questions’ for case-based instructional methodology, ($t(5) = 3.80, p = 0.013$).

Table 16
Class 1 Observational Data Mean Scores for Each Group in the ‘Working with Ideas’ Category

Groups	Working With Ideas		
	Lecture-based	Case-based	Differences
G1	7	14	7
G2	6	14	8
G3	6	13	7

G4	8	16	8
G5	8	16	8
G6	9	12	3
Mean Difference	7.333	14.166	6.833
Standard Deviation	1.211	1.602	1.941
T-Value = 8.62	P-Value = *0.000		
Note. * $p < 0.05$			

A paired sample t-test was run on the group mean scores for the lecture-based and the case-based observations involving the criteria that dealt with ‘working with ideas’. Students’ mean scores were higher after the case-based instruction (14.17 ± 1.60 points) than in the lecture-based instruction (7.33 ± 1.21 points). This is a statistically significant mean increase of 6.83 points in terms of ‘working with ideas’ for case-based instructional methodology, ($t(5) = 8.62, p = 0.000$).

Table 17
Class 1 Observational Data Mean Scores for Each Group in the ‘Collaborating’ Category

Groups	Collaborating		
	Lecture-based	Case-based	Differences
G1	6	8	2
G2	4	8	4
G3	6	8	2
G4	7	11	4
G5	7	11	4
G6	8	8	0
Mean Difference	6.333	9	2.666
Standard Deviation	1.366	1.549	1.632
T-Value = 4.00	P-Value = *0.010		
Note. * $p < 0.05$			

A paired sample t-test was performed on the mean scores for the lecture-based observations and the case-based observations involving the criteria that dealt with ‘collaborating’. Students’ mean scores were higher after the case-based instruction

(9 ± 1.55 points) than in the lecture-based instruction (6.33 ± 1.37 points); a statistically significant mean increase of 2.66 points. This is a statistically significant difference in the mean scores for ‘collaborating’ in the case-based instructional methodology as compared to the lecture-based methodology, ($t(5) = 4.00, p = 0.010$).

The observations for Class 2 were recorded using a five point scale from 0 to 4 as previously explained. A summary of the results for each key category, for Class 2, is presented below in Tables 18, 19, and 20.

Table 18
Class 2 Observational Data Mean Scores for Each Group in the ‘Asking Questions’ Category

Groups	Asking Questions		
	Lecture-based	Case-based	Differences
G1	10	15	5
G2	10	13.5	3.5
G3	10	14	4
G4	11	15	4
Mean Difference	10.25	14.375	4.125
Standard Deviation	0.50	0.75	0.629
T-Value = 13.11		P-Value = *0.001	
Note. * $p < 0.05$			

A paired sample t-test was performed on the mean scores for the lecture-based observations and the case-based observations involving the criteria that dealt with ‘asking questions’. Students’ mean scores were higher after the case-based instruction (14.375 ± 0.75 points) than in the lecture-based instruction (10.25 ± 0.50 points); a statistically significant mean increase of 4.125 points. There is a statistically significant difference in the mean scores for the category ‘asking questions’ in the case-based instructional methodology over the lecture-based methodology, ($t(3) = 13.11, p = 0.001$).

Table 19*Class 2 Observational Data Mean Scores for Each Group in the 'Working with Ideas' Category*

Groups	Working with Ideas		
	Lecture-based	Case-based	Differences
G1	7	12	5
G2	6	11	5
G3	8	14	6
G4	8	12	4
Mean Difference	7.25	12.25	5
Standard Deviation	0.957	1.258	0.816
T-Value = 12.25	P-Value = *0.001		
Note. * $p < 0.05$			

A paired sample t-test was run on the group mean scores for the lecture-based and the case-based observations involving the criteria that dealt with 'working with ideas'. Students' mean scores in Class 2 were higher after the case-based instruction (12.25 ± 1.26 points) than in the lecture-based instruction (7.25 ± 0.96 points). That is a statistically significant mean increase of 5 points in terms of 'working with ideas' for case-based instructional methodology, ($t(3) = 12.25, p = 0.001$).

Table 20*Class 2 Observational Data Mean Scores for Each Group in the 'Collaborating' Category*

Groups	Collaborating		
	Lecture-based	Case-based	Differences
G1	4	10.5	6.5
G2	7	9	2
G3	7	12	5
G4	7	11	4
Mean Difference	6.25	10.625	4.375
Standard Deviation	1.5	1.25	1.88
T-Value = 4.64	P-Value = *0.019		
Note. * $p < 0.05$			

A paired sample t-test was performed on the mean scores for the lecture-based observations and case-based observations involving the criteria that dealt with ‘collaborating’. This was done to determine if there was a statistically significant mean difference in ‘collaborating’ from a lecture-based activity to a case-based activity. Students’ mean scores were higher after the case-based instruction (10.625 ± 1.25 points) than in the lecture-based instruction (6.25 ± 1.5 points). This represents a statistically significant mean increase of 4.375 in terms of ‘collaborating’ for the case-based instructional methodology over the lecture-based methodology, ($t(3) = 4.64, p = 0.019$).

The data collected and analyzed were for the purpose of comparing a new teaching methodology (case study teaching) with traditional lecture-based instruction. The effect of these teaching methodologies was made by examining data collected on student learning, the development of critical thinking skills and cognitive engagement. In Chapter 5, I will further examine the data with respect to each of the three research questions that focused this study. I will address the implications of the research, the limitations of the study, and make recommendations for further research.

Chapter 5: Discussion and Conclusion

Educators have long been advocates for greater student engagement. They want students to develop a strong work ethic and successfully complete their high school education with the skills they need to succeed in the twenty first century. This research study was designed to evaluate a teaching program that involved the use of a different teaching methodology in high school biology classes. This pedagogy was new to the teacher-researcher and her colleague although the teacher-researcher had attended a two day seminar on the process of using case studies in the classroom.

The goal of the study was to see if the new teaching methodology, namely case studies, would help students attain critical thinking skills by becoming more cognitively engaged in their learning. The study intended to provide information about this case-based teaching methodology at the secondary level, as the current research was limited.

The research questions this study focused on were:

1. Do students exposed to the case study teaching methodology demonstrate greater cognitive engagement than those taught with the traditional lecture style instructional approach?
2. What are the benefits and drawbacks of the case study teaching methodology on student learning?
3. In what ways does the case study teaching methodology affect students' use of critical thinking skills compared with students taught with a traditional lecture style instructional approach?

Each research question will be analyzed with respect to the data obtained from the study.

A variety of different t-tests were conducted to compare the results from the case-based teaching methodology and the lecture-based teaching methodology in both classes.

Students were involved in the research study for the duration of one unit, which lasted approximately four weeks during the months of May and June. This chapter will focus on the conclusions that can be drawn from the data collected over the course of the unit. The implications of this study, its limitations, and recommendations for future research will be discussed.

Conclusions Drawn from Analyzed Data

Research Question 1. Research Question 1 asked if students exposed to the case study teaching methodology demonstrate greater cognitive engagement than those taught with the traditional lecture style instructional approach.

Cognitive engagement was defined as the effort shown by a student towards understanding the knowledge and skills being studied by asking questions, generating ideas, and working collaborating with peers. The individual that is said to be cognitively engaged, according to Reading (2008), Solis (2008), and Chapman (2003), would take responsibility for the content, want to learn new applications and skills, actively construct and create within the learning situation, and demonstrate enthusiasm, curiosity and interest in the activity.

The tools used to measure cognitive engagement involved a student questionnaire constructed by the teacher-researcher and a direct observation checklist consisting of 14 criteria. Both tools were used to identify the impact of each teaching methodology on cognitive engagement.

Conclusions, for Class 1 followed by Class 2, will be drawn using the data from the observation checklist and student questionnaire.

Class 1. The paired sample t-test performed on the mean scores from the observation checklist data for Class 1 indicated that the case-based instructional methodology resulted in a significant improvement in ‘asking questions’ over the lecture-based instructional methodology.

The second category of observation checklist criteria, namely ‘working with ideas,’ showed a significant difference for the case-based instructional approach. The students generated ideas, made connections between concepts and shared ideas more regularly with the case-based instruction. The nature of the tasks embedded in the scenarios may lend themselves to these results. Moreover, the case-based instructional task had a larger group size (4 students as opposed to 2-3 students for the lecture-based task). The group size may contribute to an environment where students are more comfortable to generate and share ideas about the topics.

The paired sample t-test for the observational data associated with ‘collaborating’ resulted in a significant difference between the case-based and lecture-based instructional methodologies. The students’ mean scores were higher for the case-based instructional tasks. These results are corroborated by the observer’s anecdotal remarks as it was noted that students asked for very little clarification, and in their small groups, talked through their uncertainty about the topic. Based on these results, it appears that students in Class 1 exposed to case study teaching demonstrated greater cognitive engagement.

Class 2. The paired sample t-test result for Class 2 showed a significant difference in the students ‘asking questions’ during the case-based instructional

methodology over the lecture-based instructional methodology. The case-based instructional task involved an authentic story that drew the students together as they read through it. This made it possible for them to begin to discuss ideas as a group and look for answers upon finishing the reading. The lecture-based assignment involved a very small amount of reading followed by students answering questions. Students generally read the short passage on their own and then began independent work. There was a difference in the approach to the assignment and the amount of interaction that occurred while engaged in the task that may have impacted the results.

The students' mean scores for 'working with ideas' were significantly different for Class 2. The case-based instructional approach resulted in a mean increase of 5 points over the lecture-based approach. The students immediately began to read the case study together and talk about the questions that followed. They gave their opinions and generated ideas and questions together. This enthusiasm was not observed with the lecture-based assignment.

The category of observations on 'collaborating' resulted in a statistically significantly higher mean score for the case-based instruction method. The anecdotal remarks indicate that students became quite animated at times during their discussion of "The Galapagos" case study. The small groups of students shared views, thoughts and concerns about the task.

These results appear to support a greater cognitive engagement with a case study teaching methodology for Class 2 over the course of the unit of study. Klein (n.d.) claimed a similar finding in his study with general biology students. He concluded that

with the use of case studies his students became more motivated and engaged in the learning of the course content.

The questionnaire given to the students outlined their views of engagement. Their perceptions of what it meant to be cognitively engaged were similar to the observations that were recorded during the case-based instructional task. The students exhibited enthusiasm, and were completely involved in generating ideas and answers. They were 'lost' in the task; immersed in their learning as they worked through the task. The students demonstrated curiosity and interest in the activity by being involved in conversations with their classmates, recording details, generating ideas and listening to their group members. The qualitative data supports that students' in Class 2 were more cognitively engaged during the case-based teaching task in contrast to the lecture-based teaching task.

Research Question 2. Research Question 2 asked, "What are the benefits and drawbacks of the case study teaching methodology on student learning?"

The measurement tools used for this research question involved two assignments and one unit test. The assignments and test were constructed by the teacher-researcher and her colleague. For the purpose of validity, each artifact was scored by the individual classroom teacher. This was followed by all of Class 1's artifacts being re-scored by the teacher-researcher. Ideally all of Class 2's artifacts should have been re-scored by the colleague to increase validity. However, the teacher-researcher felt that the time and effort put forth by the colleague was already significant and did not want to further burden him.

An independent sample t-test was conducted to determine if the mean score differences between the two classes was significant. The mean score for Class 2 was higher on Assignment 1, and there was a significant difference found between the classes. Case-based teaching resulted in a significant improvement in assignment scores for Class 2. Based on these results, there is an improvement in student learning for Class 2 owing to the case-based teaching methodology utilized. These findings are consistent with Farahani & Heidari (2013) who stated that this instructional method promotes the accessing of prior knowledge and increases the depth of student learning. Skolnick (2009) found that case study teaching methodology had a statistically significant improvement on academic achievement with the high school biology classes involved in his research study. He performed t-tests comparing an experimental group (case study teaching) and a control group (traditional teaching) during two study quarters in the school year.

The mean score for Class 2 on the second assignment was higher but the independent sample t-test showed that there was not a significant difference between the mean scores for Class 1 and Class 2.

Class 1 did have an increase in their mean score from Assignment 1 to Assignment 2. This increase was greater than the increase Class 2 had from Assignment 1 to Assignment 2. Although the assignments and content covered were different, perhaps there is still a pattern that can be noted. Class 1's overall mean score could be attributed to the case-based teaching methodology as they completed Assignment 2 immediately following that instructional method. Class 2's slight increase may be the result of the 'carry over' effect as they had already been exposed to the case-based

teaching methodology during the first half of the unit, and it may have impacted their work on the second assignment. Gijbels et al. (2003) in their meta-analysis discovered that the engagement of the students and retention of knowledge was higher with Problem-based Learning. The case used by Class 2 in their case-based instructional section of the unit was a Problem-based Learning case called “The Galapagos”. The students spent four full classes completing the activity. This may account for the ‘carry over’ effect mentioned above.

The final artifact to address this particular research question involved a unit test. The two classes had mean scores that were very close. The independent sample t-test results showed that there was no significant difference between the mean scores for Class 1 and Class 2. The data support the conclusion that the students learning that occurred in each of the two classes was similar. The standard deviation for Class 1 is smaller than Class 2. Class 2 scores are more dispersed for this test than those of Class 1. This result is supported by Albanese & Mitchell (1993) where they found that Problem-based Learning, which is a type of case study that was used in this research, was more nurturing and enjoyable, but students generally did not do better on test-based assessments or examinations.

It would have been beneficial to analyze the unit test in a different format. Each individual question could have been categorized as to the outcome it tested in the unit. The questions resulting from case studies and the questions resulting from the lecture based instruction could have been statistically analyzed for each student in the two classes to determine if there was an improvement in critical thinking with a particular instructional method. Unfortunately, this analysis was not possible as the unit tests were

not photocopied and had been returned to the students after the multiple cumulative marking was completed.

To fully understand the functionality of case-based teaching, one needs to identify the concerns or drawbacks that exist with this method and address them as they pertain to the work being done.

One drawback of the case-based teaching methodology is the time it required to introduce and carry out the individual cases. This was the first time both the teacher-researcher and her colleague had worked with case studies in a classroom setting. This resulted in a great deal of collaboration and a longer time frame for addressing the material in class. An increase in speed was experienced as they became more comfortable with each case. However, because of the constraint of time associated with the semester system, students may not be exposed to all of the learning outcomes in the curriculum over the course of the semester and, as a result, miss out on learning this content.

Another drawback, particularly when cases are open-ended, is the unpredictability associated with the specific outcomes the student actually achieves. This may limit the development of specific knowledge or skills that a teacher considers necessary for the students to learn. However, a more directive case scenario would solve this dilemma.

A final drawback would be the participation level of all group members if the groups became too large. It is important to monitor group dynamics and to ensure that each student is a productive member of the group. This requires an ongoing facilitation and involvement with each group which can become a difficult task with larger classes.

Research Question 3. Research Question 3 asked in what way does the case study teaching methodology affects students' use of critical thinking skills compared with students taught with a traditional lecture style instructional approach?

The design setting of this study did not allow for cross comparison of classes with respect to the Critical Thinking Applied Measure. The pre-test was given at the beginning of the study and the post-test was administered at the conclusion of the unit of study. Both Class 1 and Class 2 had case-based teaching and lecture-based teaching when the post-test was given. Hence, the data collected was analyzed for each class individually.

The Applied Critical Thinking Measure (Appendix C) was the measurement tool used to determine the impact of case-based teaching and lecture-based teaching on critical thinking skills.

A paired sample t-test was conducted on the pre-test and post-test scores for each student in Class 1. There was not a statistically significant difference between the mean scores for the pre-test to the post-test for this class. This suggests that Class 1 did not have a change in their critical thinking skills as a result of the teaching approaches used in this unit of study.

Class 1 was the colleague's biology class. These students did not have any relationship to the teacher-researcher and, therefore, it is possible they may not have put in their best effort when completing the pre-test or post-test scenarios, thus showing limited improvement. The colleague had no previous training in the delivery of case studies; this may have impacted the effect of the cases as a tool for improving critical thinking skills. The time of day may have impacted the results. Class 1 was held in the

afternoon while Class 2 had their biology class in the morning. This may have had an effect on the attention and concentration of students. Finally, although each class was given three case studies they varied in style; Class 1's cases were all of the Interrupted Case study style whereas Class 2 involved one case that was a Dilemma/Decision, one was the Interrupted style and the final case was a Clicker/Interrupted Case style. This variation may have had an impact on the skills the students learned during the case-based instructional time.

The paired sample t-test conducted on Class 2 students indicated a statistically significant difference in mean scores from the pre-test to the post-test. This suggests that throughout the unit of study Class 2 improved on their use of critical thinking skills as a result of the overall combination of teaching methods used.

The teacher-researcher had attended a two day seminar on case studies which may have had an impact on the teaching of the cases. The teacher-researcher may unknowingly have shown a difference in enthusiasm toward this type of lesson format over lecturing. Additionally, the novelty of the case study methodology for students may have increased their effort over the time frame of this study.

Implications of Research

This research study addressed an identified knowledge gap of case-based teaching methodology at the high school biology level. There is empirical evidence of its use in medicine, post- secondary education and the business field, but very limited information or research at the secondary level exists. The meaningful results that can be derived from the data are that case-based teaching improves student learning and increases student cognitive engagement. This finding is further supported by Rotgan et al. (2011) who

stated that when “students’ progress with their learning in Problem-based Learning, their ...cognitive engagement increases” (p. 476).

The possibility that exists if students are cognitively engaged in a science course, like the biology course described here, is that they may choose to enroll in more science related classes at the secondary or post-secondary level.

The improvement in student learning could lead to higher grades and a future interest in science related fields of study for career opportunities. The case-based learning allows the student to work with authentic types of situations and make connections with career options and opportunities.

The data for Class 1 did not strengthen the claim that case-based teaching in biology would impact the use of critical thinking skills. However, Class 2 did have a significant difference in their mean scores from the pre-test to the post-test. Given the relatively short duration of the study, the fact that the students showed a gain in these skills is noteworthy. The critical thinking measure that was used allowed students to identify the purpose, reference information, make connections, ask questions, draw conclusions and justify them.

Limitations of the Study

The limitations of this study include the time of day the class was held, the fact that there was only one unit of study included in the data collection, and the small sample size. The relationship that existed between the teacher and his/her students was not the same. This needs to be considered along with the fact that the researcher was one of the teachers and her expectations/hypothesis/knowledge of the effects of case studies on

student learning may have impacted how she delivered the course content or recorded qualitative classroom observations.

Biology for Class 1 occurred at 14:45 every afternoon while Class 2 had biology at 09:00 am each day. The time of day likely plays a role in the amount of effort put forth by students. My experience in teaching has seen that the earlier in the day a class occurs, generally the more productive the students are. The research study occurred during the latter part of April and continued through till early June. The students did have another short unit after this study so I do not feel that they were less motivated because of the time of year.

The unit was four weeks in duration and involved six case studies. The shortness of the study places limitations on the development of critical thinking skills as students would generally need a longer period of time to develop their confidence and their development and application of these skills. Moreover, case studies may exist that were not used in this study and lend themselves more appropriately to developing students' critical thinking skills.

The sample size was 39, and the study occurred in a small rural high school. This would limit generalizing the results to other settings. The sample size will impact the statistical validity of some t-tests as it violates the assumption of the test procedures, which require a certain size sample.

The students in the teacher-researcher's class may be more open to answering questions and participating, because she was their teacher (Hawthorne Effect). However, being aware of observer bias, the teacher-researcher was adamant about conversing with

her colleague on any observations or field notes collected. The criteria checklist for the observations was closely adhered to.

The background of the students in the study is similar (mostly Caucasian and middle class) which limits generalization to a more diverse cultural setting.

The constraint of time was also a limitation with this study as the amount of knowledge that can be taught using case-based teaching requires more time than lecture-based instruction.

A final limitation could be the students themselves as they may not have tried their best on certain tasks. This wasn't evident on the two assignment artifacts (Assignment 1 and 2) as they were scored and included in the students final biology mark. However the pre-test and post-test on critical thinking did not have any impact on the students biology grade. As a result, the effort put into this task was noticeably different for the classes. This was observed by both the teacher-researcher and her colleague as they scored the papers for the purpose of statistical analysis.

Recommendations for Future Research

Student learning was improved for Class 2 over both halves of the unit. The carry over effect which may have occurred could be studied further to determine if it was the cause of the improvement in grades at the end of the unit.

This study involved two educators teaching one unit using two different methods. The order of the teaching methods may have had an impact on student learning and/or the development of skills. Does the order of the teaching method impact learning? This is a topic that requires more careful research.

The complete unit or perhaps multiple units could be taught using case studies. This research could be done to determine if critical thinking and student learning would improve more significantly with an increase in time and exposure to this teaching methodology.

A study of the comparisons of these two teaching methods involving teachers using the exact same type of cases could be further researched. There was similarity in the format of the cases used in each class but they were not of the exact same type. Class 1 used three cases that were classified as Interrupted/Dilemma/Decision cases whereas Class 2 used one Dilemma/Decision case, one Interrupted Case and one Clicker/Interrupted Case study.

Conclusion

As outlined in the introduction, one of our roles as educators is to meet the demands of our students by using a variety of teaching approaches. The pedagogy behind this is that we will be able to address the needs of our students and help them move forward in their learning. Since we are working with future adult citizens of the twenty first century, where the demand for skills is significant, we want to do our educational best to provide them with the opportunity to learn and practice the skills they need to become productive and successful citizens.

This study, in spite of its modest scope, provides a perspective of the possible benefit of case-based teaching. It demonstrates that students are more engaged in their learning with case-based instruction. They enjoyed and were enthusiastic about the authentic situations that allowed them to generate ideas, questions, answers, and to work collaboratively as a member of a group. The increase in cognitive engagement that was

observed lends itself to improvement in student learning. Harris (2011) found this in his study as well. As McClure (2012) explained, we stimulate student interest by showing them the content's real world connections and involving them in activities that inspire creative applications. This may lead students to want to pursue more science related courses or careers.

As Willms, Friesen and Milton (2009) indicated, when students have more interesting assignments and the opportunity to collaborate and participate in groups it can have a positive contribution toward their success. The data from this study supports that student learning increased when students were involved in the case-based teaching tasks. The tasks incorporated the aforementioned attributes.

According to the National Center for Case Study Teaching in Science (NCCSTS) case studies were “found to be a powerful pedagogical technique for teaching science, they can be used not only to teach scientific concepts and content, but also process skills and critical thinking” (NCCSTS, 2012, p. 1). Another significant aspect of case studies is their propensity to help with long term retention of information. The structure of a case is normally a short narrative story. According to Gottschall, the human brain is designed to remember stories. This leads to the possibility of students using the stories as scaffolding to create meaning with the course content they are learning. Thus it's possible to infer that there is a greater retention of the science knowledge when this information is presented in story format (Gottschall, 2013).

Despite the limitations of the development and use of critical thinking skills in this study, the students did experience tasks that required them to analyze a problem, make connections to their own previous knowledge, and make an evaluation or judgment

by ascertaining the quality of the information. All of these skills as outlined by Bissell (2006) are aspects of a critical thinker. These skills fall under the higher level of Bloom's Taxonomy which is similar to Facione's (1990) list of critical thinking skills. This may be the catalyst needed for biology students to become critical thinkers, and ideally they would be provided with additional time and support to develop these skills. An extended research study would not only provide the opportunity to nurture these skills but to gain further insight into the use of case studies. Given that we are trying to educate students for a world that is rapidly changing, this teaching approach could be included as a technique that has the potential to teach them the skills they require to succeed.

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Appendix A1

Oral Recruitment Communication for Mrs. McCallum's Biology class

Third Party Individual: Good morning, my name is _____,

I am a teacher at this school. Mrs. McCallum is a student at the University of Manitoba working on her Master's Degree in Education. She is working under the supervision of Professor Barbara McMillan. She is interested in learning if a new instructional method of teaching would help to improve a student's (your) critical thinking skills and cognitive engagement in biology. Critical thinking is high level thinking that involves analysis, evaluation, reasonableness, reflection and self-correctiveness. Cognitive engagement is the effort shown by you towards understanding the knowledge and skills being studied.

She is going to teach a section of two different units of the Grade 12 Biology course using this teaching strategy. The strategy involves using case studies or authentic stories, with an educational message, to help you learn the content as opposed to the traditional lecture method.

This study will be done throughout the semester as part of our regular class instruction. It does not involve any additional work on your part. You, as students in grade 12 biology, will be learning the content by this method regardless of whether you choose to participate in the study or not.

The **regular** Grade 12 Biology course curricular outcomes will be taught. [You will be learning all the material necessary to complete your Grade 12 Biology credit].

Data that will be collected includes pre-test and post-test results on Applied critical thinking skills, two assignments on the cases studied, **student observations**, a short interview and post survey on cognitive engagement. These forms of data will be collected from all students in the class as part of the course requirements. However, only the data from students participating in the study will be used in the research report.

The data will only be analyzed at the end of the term once final marks are completed. Your participation is anonymous until the final marks are submitted in June, at which point the participants will be identified to allow for the use of their data for research analysis. Mrs. McCallum will not know if you have chosen to participate or not until that point in time. Participation is 100% voluntary and you can

withdraw your participation at any time throughout the semester by telling me (come to room 211) and completing a withdrawal form, **calling the school and speaking with me or emailing me at _____@_____**. There is no penalty for withdrawing. All your material will be destroyed [shredded] upon your withdrawal from the study.

I have a written consent form for you and your parents to read and sign **if you choose to participate**. Your name will not be used in any of the data analysis or final report.

Mrs. McCallum is only asking permission from you so she is able to use the same material collected in class for research purposes. It will be analyzed in order to make conclusions about whether this teaching strategy has an impact on student's critical thinking skills, cognitive engagement and learning. She would like to know if this is a strategy that would help students learn.

A copy of the final written research report can be made available to you if you request it on the participants permission form.

Do you have any additional questions or concerns about the process or how the information will be used before I hand out the forms?

All consent forms need to be returned to me directly. My room is 211 at the other end of the school from Mrs. McCallum's classroom.

If at any time you have questions about your participation or the study, please come to see me in room 211. **If your parents have questions, they can call the school at 204-_____ and ask for me or they can email me at _____@_____.**

Thanks.

Appendix A2

Oral Recruitment Communication for the participating teachers' Biology class

Third Party Individual: Good morning, my name is _____, I am a teacher at this school. Mrs. McCallum, the other biology teacher at _____ Collegiate is a student at the University of Manitoba working on her Master's Degree in Education. She is working under the supervision of Professor Barbara McMillan. She is interested in learning if a new instructional method of teaching would help to improve a student's (your) critical thinking skills and cognitive engagement in biology. Critical thinking is high level thinking that involves analysis, evaluation, reasonableness, reflection and self-correctiveness. Cognitive engagement is the effort shown by you towards understanding the knowledge and skills being studied.

Your teacher Mr. _____ is going to teach a section of two different units of the Grade 12 Biology course using this teaching strategy. The strategy involves using case studies or authentic stories, with an educational message, to help you learn the content as opposed to the traditional lecture method. Mrs. McCallum is doing this format with her biology class as well.

This study will be done throughout the semester as part of your regular class instruction. It does not involve any additional work on your part. You, as students in grade 12 biology, will be learning the content by this method regardless of whether you choose to participate in the study or not.

The regular Grade 12 Biology course curricular outcomes will be taught. [You will be learning all the material necessary to complete your Grade 12 Biology credit].

Data that will be collected includes pre-test and post-test results on Applied critical thinking skills, two assignments on the cases studied, **student observations**, a short interview and post survey on cognitive engagement. These forms of data will be collected from all students in the class as part of the course requirements. However, only the data from students participating in the study will be used in the research report.

The data will only be analyzed at the end of the term once final marks are completed. Your participation is anonymous until the final marks are submitted in

June, at which point the participants will be identified to allow for the use of their data for research analysis. Mrs. McCallum and Mr. _____ will not know if you have chosen to participate **until that point in time.** Participation is 100% voluntary and you can withdraw your participation at any time throughout the semester by telling me (come to room 211) and completing a withdrawal form, **calling the school and speaking with me or emailing me at _____@_____** There is no penalty for withdrawing. All your material will be destroyed [shredded] upon your withdrawal from the study.

I have a written consent form for you and your parents to read and sign **if you choose to participate.** Your name will not be used in any of the data analysis or final report.

Mrs. McCallum is only asking permission from you so she is able to use the same material collected in class for research purposes. It will be analyzed in order to make conclusions about whether this teaching strategy has an impact on student's critical thinking skills, cognitive engagement and learning. She would like to know if this is a strategy that would help students learn.

A copy of the final written research report can be made available to you if you request it on the participants permission form.

Do you have any additional questions or concerns about the process or how the information will be used before I hand out the forms?

All consent forms need to be returned to me directly. My room is 211 at the other end of the school from Mrs. McCallum's and Mr. _____ classroom.

If at any time you have questions about your participation or the study, please come to see me in room 211. **If your parents have questions, they can call the school at 204-_____ and ask for me or they can email me at _____@_____.**

Thanks.

Appendix B1

Student Consent Form for Teacher-researcher's Class

Research Project Title: *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*

Principal Investigator and contact information: Mrs. Joyce McCallum,
[REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
[REDACTED]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Dear Student,

I am conducting a study entitled *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*. This research is the basis of a thesis that I am working on for a Master of Education degree. I am currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. This study is being conducted under the supervision of Dr. Barbara McMillan.

As part of our regular biology classroom instruction, you will be receiving instruction using a method referred to as case-based instruction. This method of instruction involves learning the biology curriculum through educational stories based on authentic real-world situations.

The purpose of this study is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods. I am looking for new teaching strategies that may provide students with opportunities to improve their engagement, critical thinking skills and learning of the biology content.

This study will be conducted throughout the latter part of the semester in biology class. It will involve you receiving several case study lessons during class time. These lessons are interactive and focus on authentic real world issues. You will work individually and collaboratively to solve the dilemmas in the case studies.

There will be a variety of assessments throughout the two units of study. The forms of assessment will include a pre-test and post-test on critical thinking, two assignments on each unit, a post instructional survey on cognitive engagement, and participation in a semi-structured [short 5 minute] interview about your engagement in class. **Observations of your engagement, while you participate in the case studies, will be taken.** If you decide that you would like to participate, all of this information will be used as data in the study and will be completely confidential. If you choose not to participate, this information will be shredded and destroyed

prior to any data analysis for the study. No students' names will be used in any part of the research report and no recording devices of any kind will be used during the interviews.

There are no known or anticipated risks to you if you choose to participate in this study. The potential benefit may be that after being exposed to a new teaching method, you may see the link between the course content and authentic real life situations.

Your participation will be anonymous, throughout the semester, until such time that final marks are submitted to the office. A third party individual (a new teaching staff member) will distribute and collect the **consent forms**. Data collected throughout the semester will be kept in a secure location.

Your participation in this study is 100% voluntary and I want to reassure you that there is no consequence for giving or withholding your permission. The case study instructional strategy will be used to teach the content to all students in the Grade 12 Biology course regardless of their participation in this research study. Their participation or lack thereof will have no impact on your exposure to the content of the course, your grades on assignments, performance comments or relationship with the teacher-researcher (Mrs. McCallum). **I will not know if you have chosen to participate until final marks for the course have been submitted to the office in June.** In order to avoid any pressure you might feel because I am your teacher, I have asked that all returned consent forms be brought to room 211 (Mr. _____ room), not to me.

You have the right to withdraw at any point, in the semester, without a penalty of any kind. In order to withdraw from the study, you can obtain a withdrawal form from the third party individual; sign it indicating you wish to withdraw your participation **OR you can call the Collegiate at 204-_____ and ask to speak to Mr. _____ or email Mr. _____ at _____@_____ to indicate your wish to withdraw.** The data collected from you will not be used and will be destroyed. The third party individual will shred the material.

Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014. The thesis will become a public document that can be accessed through the University of Manitoba library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference.

If you wish to have a copy of the completed Master's Thesis document please indicate below:

Please email a completed copy to _____

Please mail a copy to _____
(be sure to include your full mailing address)

In summary, a participant of this research study is consenting to the following:

- Allowing for the use of their results on the pre-test and post-test of Applied Critical Thinking Skills
- Allowing for the use of their responses from the semi-structured interview conducted
- Allowing for the use of their results on the assignments completed in the units of study
- Allowing for the use of their results on the post-survey of cognitive engagement
- Allowing for the use of the direct observations made during their participation in the case study scenarios

Please discuss this letter with your parents and determine whether you wish to give consent. **Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree that you can participate as a subject.**

In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so feel free to ask for clarification or new information throughout your participation. This can be done by contacting the principal Mr. _____ at 204 _____.

The University of Manitoba may look at my research records to see that the research is being done in a safe and proper way.

This research has been approved by the superintendent (_____), principal (_____) and the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or email Margaret.bowman@umanitoba.ca.

A copy of this consent form will be given to you to keep for your records and reference.

Thank you for your time and consideration,

Mrs. J. McCallum

Participant's Signature _____ Date: _____

Appendix B2

Student Consent Form for Participating Biology Teacher's Class

Research Project Title: *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*

Principal Investigator and contact information: Mrs. Joyce McCallum, [REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
Barbara.mcmillan@umanitoba.ca

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Dear Student,

Mrs. McCallum is conducting a study entitled *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*. This research is the basis of a thesis that she is working on for a Master of Education degree. She is currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. This study is being conducted under the supervision of Dr. Barbara McMillan.

As part of our regular biology classroom instruction, you will be receiving instruction using a method referred to as case-based instruction. This method of instruction involves learning the biology curriculum through educational stories based on authentic real-world situations.

Mrs. McCallum has asked that the biology class I teach be given the opportunity to participate in this study if they so choose. This would allow the students, from both biology classes, to be exposed to the same teaching strategies.

The purpose of this study is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods. She is looking for new teaching strategies that may provide students with opportunities to improve their engagement, critical thinking skills and learning of the biology content.

This study will be conducted throughout the latter part of the semester in biology class. It will involve you receiving several case study lessons during class time. These lessons are interactive and focus on authentic real world issues. You will work individually and collaboratively to solve the dilemmas in the case studies.

There will be a variety of assessments throughout the two units of study. The forms of assessment will include a pre-test and post-test on critical thinking, two assignments on each unit, a post instructional survey on cognitive engagement, and participation in a semi-structured [short 5 minute] interview about your engagement in class. **Observations of your engagement, while you participate in the case studies, will be taken.** If you decide that you would like to participate, all of this information will be used as data in the study and will be completely

confidential. If you choose not to participate, this information will be shredded and destroyed prior to any data analysis for the study. No students' names will be used in any part of the research report and no recording devices of any kind will be used during the interviews. You will have the opportunity to read the interview transcript and make any changes you see fit.

There are no known or anticipated risks to you if you choose to participate in this study. The potential benefit may be that after being exposed to a new teaching method, you may see the link between the course content and authentic real life situations.

Your participation will be anonymous, throughout the semester, until such time that final marks are submitted to the office. A third party individual (a new teaching staff member) will distribute and collect the **consent forms**. Data collected throughout the semester will be kept in a secure location.

Your participation in this study is 100% voluntary and she wants to reassure you that there is no consequence for giving or withholding your permission. The case study instructional strategy will be used to teach the content to all students in the Grade 12 Biology course regardless of their participation in this research study. Their participation or lack thereof will have no impact on your exposure to the content of the course, your grades on assignments, performance comments or relationship with the teacher-researcher (Mrs. McCallum) or me (Mr. _____). **I will not know if you have chosen to participate until final marks for the course have been submitted to the office in June.** In order to avoid any pressure you might feel because I am your teacher, I have asked that all returned consent forms be brought to room 211 (Mr. _____ room), not to me.

You have the right to withdraw at any point, in the semester, without a penalty of any kind. In order to withdraw from the study, you can obtain a withdrawal form from the third party individual; sign it indicating you wish to withdraw your participation **OR you can call the Collegiate at 204 [REDACTED] and ask to speak to Mr. _____ or email Mr. _____ at [REDACTED]@ [REDACTED] to indicate your wish to withdraw.** The data collected will not be used and will be destroyed. The third party individual will shred the material.

Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014. The thesis will become a public document that can be accessed through the University of Manitoba library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference.

If you wish to have a copy of the completed Master's Thesis document please indicate below:

Please email a completed copy to _____

Please mail a copy to _____
(be sure to include your full mailing address)

In summary, a participant of this research study is consenting to the following:

- Allowing for the use of their results on the pre-test and post-test of Applied Critical Thinking Skills
- Allowing for the use of their responses from the semi-structured interview conducted
- Allowing for the use of their results on the assignments completed in the units of study
- Allowing for the use of their results on the post-survey of cognitive engagement

- Allowing for the use of the direct observations made during their participation in the case study scenarios

Please discuss this letter with your parents and determine whether you wish to give consent. **Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree that you can participate as a subject.**

In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so feel free to ask for clarification or new information throughout your participation. This can be done by contacting the principal Mr. _____ at 204 _____.

The University of Manitoba may look at my research records to see that the research is being done in a safe and proper way.

This research has been approved by the superintendent (_____), principal (_____) and the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or email Margaret.bowman@umanitoba.ca.

A copy of this consent form will be given to you to keep for your records and reference.

Thank you for your time and consideration,

Mr. _____

Participant's Signature _____ Date: _____

Appendix B3

Parental Consent Form for Mrs. McCallum's Biology Class

Research Project Title: Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills

Principal Investigator and contact information: Mrs. Joyce McCallum,
[REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
[REDACTED]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Dear Parent,

I am conducting a study entitled *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*. This research is the basis of a thesis that I am working on for a Master of Education degree. I am currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. This study is being conducted under the supervision of Dr. Barbara McMillan.

As part of our regular biology classroom instruction, your child will be receiving instruction using a method referred to as case-based instruction. This method of instruction involves the students learning the biology curriculum through educational stories based on authentic real-world situations.

The purpose of this study is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods. I am looking for new teaching strategies that may provide students with opportunities to improve their engagement, critical thinking skills and learning of the biology content.

This study will be conducted throughout the latter part of the semester in biology class. It will involve students receiving several case study lessons during class time. These lessons are interactive and focus on authentic real world issues. Students will work individually and collaboratively to solve the dilemmas in the case studies. This will not be the only teaching strategy used in the course [lecture-based instruction, discussions and **some laboratory investigations or experiments will be included**].

The curricular outcomes from the regular Grade 12 Biology course will be covered using these teaching strategies. At all times throughout the teaching of the course, your child's education and learning is top priority. It will not be compromised by using this new teaching strategy. I believe that it will make the content more meaningful for them [as the cases are real-world scenarios] and benefit my own professional practice.

The students will be assessed throughout each unit of study. The forms of assessment will include a pre-test and post-test on critical thinking, two assignments on each unit, a post instructional survey on cognitive engagement, and participation in a semi-structured [short 5 minute] interview about their engagement in class. **Observations of their engagement, while they participate in the case studies, will be taken.** If you decide that your child will participate, all of this information will be used as data in the study and will be completely confidential. If you choose not to participate, this information will be shredded and destroyed prior to any data analysis for the study. No students' names will be used in any part of the research report and no recording devices of any kind will be used during the interviews. Your child will have the opportunity to read the interview transcript and make any changes they see fit.

There are no known or anticipated risks to your child if they choose to participate in this study. The potential benefit may be that your child, after being exposed to a new teaching method, may see the link between the course content and authentic real life situations.

Your child's participation will be anonymous, throughout the semester, until such time that final marks are submitted to the office. A third party individual (a new teaching staff member) will distribute and collect the **consent forms**. Data collected throughout the semester will be kept in a secure location.

Your permission for your child's information to be used in this study is 100% voluntary and I want to reassure you that there is no consequence for giving or withholding your permission. The case study instructional strategy will be used to teach the content to all students in the Grade 12 Biology course regardless of their participation in this research study. Their participation or lack thereof will have no impact on the students' exposure to the content of the course, their grades on assignments, performance comments or relationship with the teacher-researcher (Mrs. McCallum). **I will not know if your child has chosen to participate until final marks for the course have been submitted to the office in June.** In order to avoid any pressure you might feel because I am your child's teacher, I have asked that all returned consent forms be brought to room 211 (Mr. _____ room), not to me.

Your child has the right to withdraw at any point, in the semester, without a penalty of any kind. In order to withdraw from the study, students and parents can obtain a withdrawal form from the third party individual; sign it indicating you wish to withdraw your participation **OR you can call the Collegiate at 204-_____ and ask to speak to Mr. _____ or email Mr. _____ at _____@_____ to indicate your wish to withdraw.** The data collected from your child will not be used and will be destroyed.

This instructional strategy will be part of the Grade 12 biology course regardless of your child's participation therefore; there will not be any form of credit or remuneration for participating in this study.

Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014. The thesis will become a public document that can be accessed through the University of Manitoba library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference.

If you wish to have a copy of the **completed Master's Thesis document** please indicate below:

Please email a completed copy to _____

Please mail a copy to _____

_____ (be sure to include your full mailing address)

In summary, a participant of this research study is consenting to the following:

- Allowing for the use of their results on the pre-test and post-test of Applied Critical Thinking Skills
- Allowing for the use of their responses from the semi-structured interview conducted
- Allowing for the use of their results on the assignments completed in the units of study
- Allowing for the use of their results on the post-survey of cognitive engagement
- Allowing for the use of the direct observations made during their participation in the case study scenarios

Please discuss this letter with your child and determine whether you wish to give consent.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree that your child can participate as a subject.

In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities.

The University of Manitoba may look at my research records to see that the research is being done in a safe and proper way.

This research has been approved by the superintendent (), principal () and the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or email Margaret.bowman@umanitoba.ca.

A copy of this consent form will be given to you to keep for your records and reference.

Thank you for your time and consideration,

Mrs. J. McCallum

Participant's Name _____

Parent's Signature _____ Date: _____

Appendix B4

Parental Consent Form for Participating Biology Teacher's Class

Research Project Title: Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills

Principal Investigator and contact information: Mrs. Joyce McCallum,
[REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
[REDACTED]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Dear Parent,

Mrs. McCallum is conducting a study entitled *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*. This research is the basis of a thesis that she is working on for a Master of Education degree. She is currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. This study is being conducted under the supervision of Dr. Barbara McMillan.

As part of our regular biology classroom instruction, your child will be receiving instruction using a method referred to as case-based instruction. This method of instruction involves the students learning the biology curriculum through educational stories based on authentic real-world situations.

Mrs. McCallum has asked that the biology class I teach be given the opportunity to participate in this study if they so choose. This would allow the students, from both biology classes, to be exposed to the same teaching strategies.

The purpose of this study is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods. She is looking for new teaching strategies that may provide students with opportunities to improve their engagement, thinking skills and learning of the biology content. She has been given permission by the principal and superintendent to conduct this research.

This study will be conducted throughout the latter part of the semester in biology class. It will involve students receiving several case study lessons during class time. These lessons are interactive and focus on authentic real world issues. Students will work individually and collaboratively to solve the dilemmas in the case studies. This will not be the only teaching strategy used in the course [lecture-based instruction, discussions and **some laboratory investigations or experiments will be included**]. The content of the grade 12 biology curriculum will be covered using these teaching strategies. At all times throughout the teaching of the course, your child's education and learning is top priority. It will not be compromised by using this new teaching strategy. I believe that it will make the content more meaningful for them [as the cases are real-world scenarios] and benefit by own professional practice.

The students will be assessed throughout each unit of study. The forms of assessment will include a pre-test and post-test on critical thinking, two assignments on each unit, a post instructional survey on cognitive engagement, and participation in a semi-structured [short 5 minute] interview about their engagement in class. I will also be making observations of their engagement while they participate in the case studies. If you decide that your child will participate, all of this information will be used as data in the study and will be completely confidential. If you choose not to participate, this information will be shredded and destroyed prior to any data analysis for the study. No students' names will be used in any part of the research report and no recording devices of any kind will be used during the interviews. Your child will have the opportunity to read the interview transcript and make any changes they see fit.

There are no known or anticipated risks to your child if they choose to participate in this study. The potential benefit may be that your child, after being exposed to a new teaching method, may see the link between the content knowledge and authentic real life situations.

Your child's participation will be anonymous as neither Mrs. McCallum (the teacher-researcher) nor I will know who the participants are during the semester. In June when the final marks have been submitted to the office we will then have access to the names of the participants for the sole purpose of using their data in the analysis.

A third party individual (not the teacher-researcher or I) will distribute and collect the **consent forms**. Data collected throughout the semester will be kept in a secure location.

Your permission for your child's information to be used in this study is 100% voluntary and I want to reassure you that there is no consequence for giving or withholding your permission. The case study instructional strategy will be used to teach the content to all students in the Grade 12 Biology course regardless of their participation in this research study. Their participation or lack thereof will have no impact on the students' exposure to the content of the course, their grades on assignments, performance comments or relationship with the teacher-researcher (Mrs. McCallum). She and I will not know if your child has chosen to participate until final marks for the course have been submitted to the office in June. In order to avoid any pressure you might feel because I am your child's teacher, I have asked that all returned consent forms be brought to room 211 (Mr. _____ room), not to me.

Your child has the right to withdraw at any point, in the semester, without a penalty of any kind. In order to withdraw from the study, students and parents can obtain a withdrawal form from the third party individual; sign it indicating you wish to withdraw your participation **OR you can call the Collegiate at 204-_____ and ask to speak to Mr. _____ or email Mr. _____ at _____@_____ to indicate your wish to withdraw.** The data collected from your child will not be used and will be destroyed.

This instructional strategy will be part of the Grade 12 biology course regardless of your child's participation therefore; there will not be any form of credit or remuneration for participating in this study.

Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014. The thesis will become a public document that can be accessed through the University of Manitoba library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference.

If you wish to have a copy of the completed Master's Thesis document please indicate below:

Please email a completed copy to _____

Please mail a copy to _____ (be sure to include your full mailing address)

In summary, a participant of this research study is consenting to the following:

- Allowing for the use of their results on the pre-test and post-test of Applied Critical Thinking Skills
- Allowing for the use of their responses from the semi-structured interview conducted
- Allowing for the use of their results on the assignments completed in the units of study
- Allowing for the use of their results on the post-survey of cognitive engagement
- Allowing for the use of the direct observations made during their participation in the case study scenarios

Please discuss this letter with your child and determine whether you wish to give consent. **Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree that your child can participate as a subject.**

In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities.

The University of Manitoba may look at my research records to see that the research is being done in a safe and proper way.

This research has been approved by the superintendent (), principal () and the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or email Margaret.bowman@umanitoba.ca.

A copy of this consent form has been given to you to keep for your records and reference.

Thank you for your time and consideration,

Mr. _____

Participant's Name _____

Parent's Signature _____ Date: _____

Appendix C1

Recruitment Script for Third Party Individual

Teacher-Researcher speaking:

Hi _____. I would like to ask if you would be willing to be a third party individual for a research study I am beginning. I am a student in the Faculty of Education of the University of Manitoba working on my Master's Degree in Education. I am working under the supervision of Professor Barbara McMillan.

The study involves teaching the Grade 12 Biology course using a new instructional method that may help to improve student's critical thinking skills and cognitive engagement in biology.

This study will begin in the second semester and be completed in June of 2014 [end of second semester].

Your role, if you accept, would be to do the following:

- i. Prior to the start of Unit 3 in the biology course you would need to come in to the biology classes [teacher-researcher and participating biology teacher] and explain to the students the purpose of this study.
- ii. You would be required to read a script with the explanation of the purpose of the study and distribute consent forms to students (parent/student consent form).
- iii. You would need to provide students with consent forms to go to their parents/guardians.
- iv. You need to explain that this study is 100% voluntary; participants can withdraw at any time by completing the withdrawal form [which you will have]; you will discuss the other key information as outlined in the consent form [consent form is in appendices]
- v. You will be responsible for collecting and storing consent forms in a locked filing cabinet of which you will have sole access. You will also distribute and collect withdrawal forms as needed.
- vi. You will need to photocopy and store assignments of all the biology students for the purpose of later distributing the participating student work to the teacher-researcher [upon submission of final grades in June].
- vii. Informing teacher-researcher, at conclusion of course and when final marks are submitted, the names of participants for the purpose of analyzing their data.
- viii. You will need to shred the documents of any students withdrawing from the research study or if they are not participating in the study.

- ix. Conducting, on four separate occasions, observations of students in the biology classes. The observations would be done by following a checklist outlined in the appendices. [**Appendix**]

Do you have any questions about your responsibilities or this study?

The signature below indicates that you are accepting the previous stated responsibilities and will carry these out throughout the second semester of this school year [2013-1014].

Name: _____

(Please print)

Signature: _____

Date: _____

Appendix C2**Consent Form for Third Party Individual**

Research Project Title: *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*

Principal Investigator and contact information: Mrs. Joyce McCallum,
[REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
[REDACTED]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Introduction: I am requesting your permission to be a third party participant in a research study called, "*Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*". I am currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. I am working on a Master of Education degree. This research study is a part of my thesis. I am looking for new teaching strategies that may provide students with opportunities to improve their engagement and thinking skills. I have been given permission by the principal and superintendent to conduct this research this semester.

Purpose of Study: The purpose is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods.

Procedures: This study will be conducted throughout the second semester in biology class. It will involve students receiving both traditional lecture-based teaching and case-based teaching. Several case study lessons will be given during the appropriate section of the unit [see unit outline in recruitment letter]. These lessons are interactive and focus on authentic real world issues. Students will work individually and collaboratively to solve the dilemmas in the case studies. The content of the grade 12 biology curriculum will be covered.

The students, in our classes, will be given a pre-test and post-test on applied critical thinking, a post instructional survey on cognitive engagement, two unit assignments and participate in a 5 minute interview about engagement. Visual observations of their engagement will be recorded as they participate in the case studies. All of this information will be used as data in our study and will be completely confidential. No students' names or your name will be used in any part of the research report. No recording devices of any kind will be used.

Benefits and Risks: There are no risks or benefits associated with this study for you.

Confidentiality and Anonymity: Your name will not be included in any of the data collected nor will it be stated in the thesis unless you indicate otherwise by providing a written request to have your name included.

No student information will be available until final marks for the biology course are submitted. After final marks have been submitted, I [teacher-researcher] will need access to the participating students' marks to begin the analysis of the collected material. Data collected throughout the semester will be kept in a locked filing cabinet to which you, the third party individual will have sole access. Signed consent will be obtained from the parents/student involved in the study.

You will agree to keep all information collected during this study confidential and will not reveal by speaking, communicating or transmitting this information in written, electronic (disks, tapes, transcripts, email) or in any other way to anyone outside the research team.

Compensation: There will not be any form of credit or remuneration for participating in this study.

Right to Withdraw: Participation in this study is 100% voluntary. If at any time you wish to withdraw your participation you would need to indicate in writing this request and submit it to the teacher-researcher.

Debriefing: Debriefing will occur prior to the beginning of the study to review responsibilities.

Dissemination and destruction: Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014.

The thesis will become a public document that can be accessed through the U of M library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference

If you wish to have a copy of the completed document please indicate below:

Please email a completed copy to _____

Please mail a copy to _____

_____ (be sure to include your full mailing address)

In summary, as a third party individual for this research study, you are consenting to the following:

- Prior to the start of Unit 3 in the biology course you would need to come in to the biology classes [teacher-researcher and participating biology teacher] and explain to the students the purpose of this study.

- You would be required to read a script with the explanation of this study and distribute consent forms to students.
- You would need to provide students with consent forms to go to their parents/guardians.
- You need to explain that this study is 100% voluntary; participants can withdraw at any time by completing the withdrawal form [which you will have]; you will discuss the other key information as outlined in the consent form [consent forms are in appendices]
- You will be responsible for collecting and storing consent forms in a locked filing cabinet of which you will have sole access. You will also distribute and collect withdrawal forms as needed.
- You will need to photocopy and store assignments of all the biology students for the purpose of later distributing the participating student work to the teacher-researcher [upon submission of final grades in June].
- Informing teacher-researcher, at conclusion of course and when final marks are submitted, the names of participants for the purpose of analyzing their data.
- You will need to shred the documents of any students withdrawing from the research study or if they are not participating in the study.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact

any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or Margaret.bowman@umanitoba.ca

A copy of this consent form has been given to you to keep for your records and reference.

-----Provide for Signatures as Required-----

Participant's Signature _____ Date: _____

Researcher and/or Delegate's Signature: _____ Date: _____

Appendix C3**Oath of Confidentiality**

I understand that as a third party assistant for a study being conducted by Mrs. Joyce McCallum, teacher at Morden Collegiate and graduate student in Education at the University of Manitoba under the supervision of Professor Barbara McMillan, confidential information will be made known to me.

I agree to keep all information collected during this study confidential and will not reveal by speaking, communicating or transmitting this information in written, electronic (disks, tapes, transcripts, email) or in any other way to anyone outside the research team.

Name: _____ Signature: _____
(Please Print)

Date: _____

Witness Name: _____ Witness Signature: _____

This Oath of Confidentiality was designed based on the template from McMaster's University from <http://reo.mcmaster.ca/educational-resources>.

Appendix D1

Recruitment/Collaboration Agreement

This form is to outline the responsibilities of the participating biology teacher involved in the research study.

He will be teaching the Grade 12 Biology course over the second semester [same curricular outcomes/same time frame].

His class of students will be the control group for half of the first unit and the experimental group for the second half of the first unit. This will be the opposite of the teacher-researchers class.

Unit of Study		Control Group (Lecture-based teaching)	Experimental Group (Case study teaching)
Unit 3: Evolutionary Theory and Biodiversity	SLO (B12-3-01 to B12-3-07)	Participating Biology Teacher	Teacher-Researcher
	SLO (B12-3-08 to B12-3-12)	Teacher-Researcher	Participating Biology Teacher

His class of students will be given the same presentation about the project outline from the third party individual and given the participant permission forms.

As the participating biology teacher you will be responsible for the following:

- i. Planning of the lessons of the two units, used in the research study, in collaboration with the teacher-researcher
- ii. Teach the two units of study following the outline above (each unit will involve traditional lecture-based instruction and case-based instruction)
- iii. Use the same qualitative and quantitative data collection methods as the teacher-researcher [pre-and post-test on Critical Thinking, direct observations, two assignments, semi-structured interviews, and post survey on cognitive engagement].
- iv. Evaluate the pre- and post-test on Applied Critical Thinking, record the direct observations, evaluate the two assignments using the assessment rubric [rubric included in appendices] and evaluate the post survey on cognitive engagement.

- v. Upon completion of the course and submission of final grades, provide the teacher-researcher with the class data collected for the participants of the study.

Do you have any questions about this study or your responsibilities?

The signature below indicates that you are accepting the previous stated responsibilities and will carry these out throughout the second semester of this school year [2013-1014].

Name: _____

(Please print)

Signature: _____

Date: _____

Appendix D2**Consent Form for Participating Biology Teacher**

Research Project Title: *Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*

Principal Investigator and contact information: Mrs. Joyce McCallum,
[REDACTED]

Research Supervisor and contact information: Prof. Barbara McMillan,
[REDACTED]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Introduction: I am requesting your permission to be a participating teacher in a research study called, "*Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills*". I am currently enrolled in the Faculty of Graduate Studies at the University of Manitoba. I am working on a Master of Education degree. This research study is a part of my thesis. I am looking for new teaching strategies that may provide students with opportunities to improve their engagement and thinking skills. I have been given permission by the principal and superintendent to conduct this research this semester.

Purpose of Study: The purpose is to determine if students will develop critical thinking skills and be more engaged in the biology curriculum with the use of case study instructional methods.

Procedures: This study will be conducted throughout the second semester in our biology classes. It will involve students receiving both traditional lecture-based teaching and case-based teaching. Several case study lessons will be given during the appropriate section of the unit [see unit outline in recruitment letter]. These lessons are interactive and focus on authentic real world issues. Students will work individually and collaboratively to solve the dilemmas in the case studies. The content of the grade 12 biology curriculum will be covered.

The students, in our classes, will be given a pre-test and post-test on applied critical thinking, a post instructional survey on cognitive engagement, two unit assignments and participate in a 5 minute interview about engagement. Visual observations of their engagement will be recorded as they participate in the case studies. All of this information will be used as data in our study and will be completely confidential. No students' names or your name will be used in any part of the research report. No recording devices of any kind will be used.

Benefits and Risks: As this is a new teaching method, there may be additional time required to cover the material. This may impact the time frame needed to complete a unit and may result in difficulty finishing all curricular outcomes in the course.

The benefits may be that as a participating teacher, you are exposed to a new teaching method that allows your students to link content knowledge to authentic real life situations. [Case studies]

Confidentiality and Anonymity: Your name will not be included in any of the data collected nor will it be stated in the thesis unless you indicate otherwise by providing a written request to have your name included.

No student information will be available until final marks for the biology course are submitted. After final marks have been submitted, I [teacher-researcher] will need access to the participating students' marks to begin the analysis of the collected material. Data collected throughout the semester will be kept in a locked filing cabinet to which the third party individual will have sole access. Signed consent will be obtained from the parents/students involved in the study.

You will agree to keep all information collected during this study confidential and will not reveal by speaking, communicating or transmitting this information in written, electronic (disks, tapes, transcripts, email) or in any other way to anyone outside the research team.

Compensation: There will not be any form of credit or remuneration for participating in this study.

Right to Withdraw: Participation in this study is 100% voluntary. If at any time you wish to withdraw your participation you would need to indicate in writing this request and submit it to the teacher-researcher.

Debriefing: Debriefing will occur prior to the beginning of each unit and collaboration will be ongoing as we progress through each unit of study.

Dissemination and destruction: Data collected will be destroyed upon publication of the Master Thesis. This should be approximately December of 2014.

The thesis will become a public document that can be accessed through the U of M library system. If the possibility presents itself, the thesis may be published in a referred journal or presented at a local or national conference

If you wish to have a copy of the completed document please indicate below:

Please email a completed copy to _____

Please mail a copy to _____
(Be sure to include your full mailing address)

In summary, as a participant biology teacher for this research study, you are consenting to the following:

- Planning the lessons for the units of study with the teacher-researcher
- Teaching the curricular outcomes for each unit of study with either the traditional lecture-based method or the case-based method
- Assessing and evaluating with the pre-test and post-test of Applied Critical Thinking Skills
- Allowing the teacher-researcher to conduct semi-structured interviews
- Assessing and evaluating two assignments completed in each of the units of study
- Assessing and evaluating the post-survey of cognitive engagement
- Recording direct observations of students made during their participation in the case study scenarios

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122 or Margaret.bowman@umanitoba.ca.

A copy of this consent form has been given to you to keep for your records and reference.

-----Provide for Signatures as Required-----

Participant's Signature _____ Date: _____

Researcher and/or Delegate's Signature: _____ Date: _____

Appendix E1

Assessment: Pre-Test and Post-Test for Critical Thinking Skills

Name: _____ **Class** _____

Applied Critical Thinking Measure
Pre-test

The purpose of this measure is to determine the degree to which your responses to various events reflect critical thinking. Critical thinking is defined, briefly, as the process of making a justified decision that involves (1) identifying the objective, and (2) either drawing upon relevant existing information to make a justified decision, or specifying what additional information would be needed to make a justified decision. In this measure, you will be asked to respond to various events that most people are likely to be familiar with. More specifically, after reading the short description of a particular event, you will be asked to either (a) make a decision that can be justified on the basis of existing information (in the short description) and explain why your decision is most appropriate (i.e., justification), or (b) specify what information you would need in order to make a justified decision. To illustrate, a sample event is provided below:

Two candidates are competing for an upcoming election for the position of student council president in this university. Candidate A has served on the student council for three years and has outlined a firm plan to look at the most important issues that students are facing. Candidate B was the student council vice-president last year and appears to be very well liked by fellow students when delivering campaign speeches. Which candidate would you vote for?

(circle one) CANDIDATE A CANDIDATE B NOT SURE

In the boxes below, if you chose CANDIDATE A or CANDIDATE B, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important and relevant things (one point per box) you want to know before deciding which candidate to vote for?

1.	
2.	
3.	

Scenario 1:

A new device, called the PowerFit, has been developed by athletic researchers. This device is known as an Electric Muscle Stimulator (EMS) and it develops selected muscle groups by controlled electrical stimulation, even while sitting or lying down. For example, a 15-minute application can yield the same strengthening benefits as a strenuous 2-hour workout. This device is expected to retail for under \$100, which is far less than most fitness memberships. Would you buy the Powerfit?

(circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you want to know before deciding whether or not to buy the Powerfit?

1.	
2.	
3.	

Scenario 2:

To give students from low-income families the opportunity to attend better quality schools, the provincial government is considering the use of private school vouchers. These vouchers would be derived from taxpayer dollars that would pay for all or most of the cost for students from low-income families to attend private schools. With these vouchers, parents now have more choice over which school they would like their children to attend. Do you feel these vouchers would help improve the overall level of educational achievement among all students from low-income families?

(circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding if the vouchers improve the level of educational achievement among all students from low-income families?

1.	
2.	
3.	

Scenario 3:

Imagine being able to read a 40-page textbook chapter in under 10 minutes.

Students who have purchased the Castle Speed Reading Program can read faster with greater accuracy. The Castle Speed Reading Program with its patented Recursive training method has been found to be more effective than a number of comparable programs.

Though the price of this program seems rather expensive at \$400, many have concluded that it is indeed worth the money when the program can help students spend less time reading and yet obtain higher grades. Would you buy this program or recommend it to others?

(circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding to buy this program or recommend it to others?

1.	
2.	
3.	

Scenario 4:

Recently, a leading medical journal published a report that found talking on a cellphone while driving significantly increased a person’s risk of an accident. As a result, the provincial government will have its members of the cabinet vote on whether or not talking on a cellphone while driving should be made illegal. Do you agree that talking on a cellphone while driving should be made illegal?

(circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding whether cellphone usage while driving should be made illegal?

1.	
2.	
3.	

Scenario 5:

According to a recent report, in Canadian prisons, the sentences are too short and the time spent behind bars is too easy. In fact, a considerable number of those convicted of violent crimes are released before they serve even a third of their expected sentences. Do you agree that the prison system in Canada is far too soft, especially with more serious offenders?

(circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding whether the Canadian prison system is far too soft, especially with more serious offenders?

1.	
2.	
3.	

Name: _____

Class: _____

Applied Critical Thinking Measure
Post-test

The purpose of this measure is to determine the degree to which your responses to various events reflect critical thinking. Critical thinking is defined, briefly, as the process of making a justified decision that involves (1) identifying the objective, and (2) either drawing upon relevant existing information to make a justified decision, or specifying what additional information would be needed to make a justified decision. In this measure, you will be asked to respond to various events that most people are likely to be familiar with. More specifically, after reading the short description of a particular event, you will be asked to either (a) make a decision that can be justified on the basis of existing information (in the short description) and explain why your decision is most appropriate (i.e., justification), or (b) specify what information you would need in order to make a justified decision. To illustrate, a sample event is provided below:

Two candidates are competing for an upcoming election for the position of student council president in this university. Candidate A has served on the student council for three years and has outlined a firm plan to look at the most important issues that students are facing. Candidate B was the student council vice-president last year and appears to be very well liked by fellow students when delivering campaign speeches. Which candidate would you vote for?

(circle one) CANDIDATE A CANDIDATE B NOT SURE

In the boxes below, if you chose CANDIDATE A or CANDIDATE B, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important and relevant things (one point per box) you want to know before deciding which candidate to vote for?

1.	
2.	
3.	

Scenario 1:

When we work out, our muscles are often working at high intensities, like football or basketball players. When our muscles are working, they're also creating what is known as lactic acid. As the amount of lactic acid in our bodies increase, our performance begins to decline. One type of drink that is becoming more known among athletes is a new oxygen-enriched water. Compared to regular water, the new oxygen-enriched water contains 20 times the normal amount of oxygen. Because oxygen breaks down lactic acid, this product is more in demand than ever. At \$2.25 per 500 ml bottle, would you buy this new oxygen-enriched water?

(Circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding to buy this new product?

1.	
2.	
3.	

Scenario 2:

According to a research firm in Vancouver, Ontario ranks dead last of all 10 provinces for spending on higher learning. This clearly shows a crisis in its ability to handle the projected increase in enrollment next year. With the largest university classes, second highest tuition fees, and the smallest operating grants in the country, Ontario has placed 10th in Canada for educational quality. Based on this information, do you feel that the level of educational quality in Ontario universities is the lowest in Canada?

(Circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding if the level of educational quality in Ontario universities is the lowest in Canada?

1.	
2.	
3.	

Scenario 3:

Over the past few years, many people have become increasingly concerned about the quality of care provided in hospitals. In fact, a medical report found that, in one region, more than 40 potentially harmful drug errors daily were found on average in hospitals. Based on this information, would you conclude that this represents a serious health issue?

(Circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding whether this is a serious health issue?

1.	
2.	
3.	

Scenario 4:

A recent study found that those who ate more chocolate tended to have lower blood pressure. In that student, the average 50-year-old who ate chocolate regularly had lower blood pressure than that of the average 30-year-old who ate hardly any chocolate. Based on the results of this study, do you feel that eating chocolate can help reduce one's blood pressure?

(Circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding whether eating chocolate can help reduce one's blood pressure?

1.	
2.	
3.	

Scenario 5:

Last winter many regions in Canada have endured record high temperatures. For example, during the month of January, the temperature went up to 18 degrees (Celsius) in some places. While much has been discusses about the effects of global warming, researchers have concluded that the record high temperatures that have occurred during this winter clearly indicate that global warming is definitely happening. Do you feel that this information confirms or proves that global warming is definitely happening?

(Circle one) **YES** **NO** **NOT SURE**

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you would want to know before deciding whether global warming is the cause of the record high temperatures?

1.	
2.	
3.	

This critical thinking measurement tool was provided, with permission, by Dr. Rob Renaud. (University of Manitoba)

Appendix E2

Critical Thinking Rubric

Applied Critical Thinking Measure Sample Scoring Key

Critical thinking can be defined as the process that leads one to making a justified choice. In order to make a justified choice, one must be able to (1) identify the objective and (2) either draw upon existing information or obtain new information that is relevant to the objective. The score of each question is determined by the number of points that are relevant to the objective.

Within each question, each statement or question should be compared to the main objective of the situation.

For example, in the PowerFit question, the objective is to determine whether or not the device actually develops or strengthens muscles. Basically, each point either (1) refers directly, (2) refers vaguely or indirectly, or (3) is irrelevant.

So far, it appears that most students have little difficulty in identifying the main objective/question. This indicates that each situation is familiar to most students. The main source of variability in responses seems to be in the degree of justification or questioning that would enable justification.

Rather than asking students to simply list as many statements or questions as they can think of, students are asked to list three with one distinct statement/question per box. This should help elicit critical thinking even more closely as it asks students to evaluate and choose only the best reasons and enable scoring to be more valid as the number of distinct statements/questions will be fewer and in a clearer format (i.e., in the boxes). Each question is designed to portray a product or a situation that most high school students would likely be familiar with and to encourage the student to respond quickly with either a YES, NO or NOT SURE answer. In addition, each question is either worded quite vaguely or is missing vital information.

Therefore, a student is most likely to demonstrate his/her critical thinking skill not by quickly accepting or rejecting what is proposed in the question, but rather by asking questions that would clarify his/her understanding of the product or situation so that a more informed choice can be made. **In most cases, a student will obtain a higher score in a particular question by either selecting NOT SURE and asking three relevant and specific questions, or outlining three specific flaws or missing pieces of information to support a NO answer. Occasionally, there may be an exception where a student may select YES and has provided up to three relevant and specific points to support that choice.**

Scoring key for YES, NO and NOT SURE answers

YES
<p>1. "This is beneficial..." - "this is important..." - "this is needed..." - "I agree..." (applies either to self or others)</p> <p>a. Reason is related to the objective (assumption, prediction, better than _____) 1 point</p> <p>b. No additional reason provided - reason simply reiterates information in the question - nothing beyond "this is important..." 0 points</p>
<p>2. Asks or implies a question</p> <p>a. Relevant and specific (i.e., requires a specific answer other than <i>yes</i> or <i>no</i>) 1 point</p> <p>b. Relevant and vague (i.e., can be answered with either <i>yes</i> or <i>no</i>) - "need to know more..." 0 points</p>
<p>3. "I am curious to see what happens..." 0 points</p>
<p>4. "It is inexpensive..." - "nothing to lose..." - "easy to try..." 0 points</p>
<p>5. "I have seen/heard of this (or something similar to this) before..." - "I have experienced this before..." - "everyone else has (is doing) it..." 0 points</p>
<p>6. Indicates a NO response 0 points</p>
<p>7. Unclear or irrelevant 0 points</p> <p>a. Not clear if answer indicates either YES, NO, or NOT SURE</p> <p>b. Not clear how statement relates to the objective</p>

NO
<p>1. "Not interested..." - "I don't believe it..." - "I disagree..." - "I don't like it..."</p> <p>a. Provides either possible reason or a seemingly feasible alternative 1 point</p> <p>b. No reason or alternative provided, nothing beyond a negative reply 0 points</p>
<p>2. "Does not apply to me..." - "Not my problem..." - (could be interested or agree if perceived as applicable)</p> <p>a. If person could easily avoid situation (e.g., buying a product) do not score</p> <p>b. If person may not be able to easily avoid situation (e.g., neighbourhood crime) 0 points</p>
<p>3. "Not worth it..." - "Too expensive..." (could be interested, but perceived benefit is insufficient)</p> <p>a. Provides either possible reason or a seemingly feasible alternative 1 point</p> <p>b. No reason or alternative provided, nothing beyond a negative reply 0 points</p>
<p>4. "Not enough specific information or evidence to be convinced..." - "would need to know _____" - "we don't know _____"</p> <p>a. Indicates what specific information or evidence would be needed (i.e., requires a specific answer other than <i>yes</i> or <i>no</i>) - implies "NOT SURE" type question 2 points</p> <p>b. Refers to needed information or evidence that is more vague (i.e., can be answered with either <i>yes</i> or <i>no</i>) - implies "NOT SURE" type question 1 point</p> <p>c. Nothing beyond "not enough information", "need more evidence", etc. 0 points</p>
<p>5. "This would be too difficult..." - "this cannot be done" (if possible, then might consider)</p> <p>a. Provides either possible reason or a seemingly feasible alternative 1 point</p> <p>b. No reason or alternative provided, nothing beyond "too difficult...", "cannot be done..." 0 points</p>
<p>6. "Probably won't work..." - "unlikely to be effective..." (although could be easy to try or might be interested)</p> <p>a. Provides either possible reason or a seemingly feasible alternative 1 point</p> <p>b. No reason or alternative provided, nothing beyond "won't work..." 0 points</p>

7. Indicates a YES response 0 points
8. Unclear or irrelevant 0 points a. Not clear if answer indicates either YES, NO, or NOT SURE b. Not clear how statement relates to the objective

NOT SURE
1. Question or statement requires specific information other than <i>yes</i> or <i>no</i> and the question/statement is relevant to the objective in that the information could conceivably determine whether one would answer YES or NO 3 points
2. Question requires a simple <i>yes</i> or <i>no</i> answer and the question is relevant in that the answer could conceivably determine whether one would answer YES or NO 2 points
3. Question or statement that says nothing beyond something like “would want to know more...” 0 points
4. Statement that indicates either YES or NO 0 points
5. Unclear or irrelevant 0 points a. Not clear if answer indicates either YES, NO, or NOT SURE b. Not clear how statement relates to the objective c. Asks about own values or feelings (e.g., “I don’t know if I would want this.”)

This critical thinking measurement tool was provided, with permission, by Dr. Robert Renaud. (University of Manitoba)

Appendix F

Classroom Observational Checklist on Engagement

Classroom Observation Protocol: Academic Year 2013-2014

Observer: _____ Observation Date: _____

Time Start: _____ Time Finished: _____

Lesson Topic: _____

Brief description of the class observed:

- Classroom setting (room 123 class, computer lab, other)
- Where in lesson sequence: beginning of lesson/unit, middle or toward end of lesson/unit)
- Any unusual disruptions during observation (fire drill, other _____)

Lesson Topic: _____

Scale for observations:

Value	Meaning
0	Not observed
1	Minimal
2	To some extent
3	Often
4	Regularly/very often

Observation Checklist:

Observe if the group is demonstrating the following behaviors with the task		0 Not observed	1 Minimal	2 To some extent	3 often	4 regularly
Listening in group						
Interacting with classmates						
Asking questions						
Answering questions						
Generating ideas						
Connecting ideas						
Sharing ideas with classmates						
Engaged in discussion with classmates						
Asking for help						
Trying to problem solve						
Articulating ideas to classmates						
Enthusiastic						
Engaging in inquiry (looking for answers/generating ideas)						
Working collaboratively						

This checklist was created with the help of the “Study of STEM learning” checklist found at

[http://www.serve.org/uploads/docs/Gen%20Documents/STEM%20Classroom%20Observation%20Protocol_2_19_13.](http://www.serve.org/uploads/docs/Gen%20Documents/STEM%20Classroom%20Observation%20Protocol_2_19_13.pdf)

[pdf](http://www.serve.org/STEM.aspx) Home Webpage: <http://www.serve.org/STEM.aspx>

Appendix G1

Assignment 1

Natural Selection Assignment

- 1.) What does a change in allele frequency indicate is occurring in a population? Support your answer by providing an example. (2 marks)
- 2.) Upon returning from the voyage on the H.M.S. Beagle, Darwin drafted two manuscripts in which he outlined his theory of natural selection. His reluctance to publish was due to several reasons. The two main aspects that he considered the most problematic were that he was unable to explain:
 - i.) the origin of the variation within populations that natural selection acted upon
 - ii.) the mechanism of the transmission of variation from one generation to the next (the way in which variations are passed from one generation to another).

Write a response to Darwin that would explain the two areas that he found most problematic. (2 marks)

- 3.) A limpet is a “snail-like” organism that lives on the ocean floor, clinging to rocks and hard surfaces. The shells that surround the limpet can range in color from white to dark brown. While limpets do have the ability to detach and move to another location, they are relatively sedentary organisms and therefore rely on camouflage to survive and protect themselves from predators.

If the ocean environment in which a population of limpets is covered with rocks that are either light-colored or dark-colored, what type of natural selection is most likely to occur in the population (i.e. stabilizing, directional, disruptive). Explain your reasoning. (3 marks)

- 4.) Consider the multi-drug resistant bacteria that causes tuberculosis when respond to the following tasks.
 - a.) Referring to the multi-drug resistant bacteria that causes tuberculosis, explain what the term “fittest” means in the phrase “survival of the fittest”. (2 marks)
 - b.) What type of adaptation would multi-drug resistant bacteria be an example of (structural, behavior, physiological)? Why would it be classified as this type of adaptation? (2 marks)
 - c.) Explain how natural selection led to changes in this population. (2 marks)

Appendix G2

Assignment 2

Hardy-Weinberg and Genetic Variation

- 1.) Distinguish between natural and artificial selection, with the use of an example. (2 marks)
- 2.) Evolution is changes in allele frequencies in a population’s gene pool. Scientists determine that a gene pool has changed by looking at the criteria for genetic equilibrium.
 - a) In terms of allele frequencies in a population, what does the Hardy-Weinberg Principle state? (1 mark)
 - b) Make the following chart on a piece of loose-leaf.

Conditions Necessary to achieve Hardy-Weinberg Equilibrium	Factors that Can Alter a Population’s Allele Frequency	How the Factors Could Alter a Population’s Allele Frequency

There are five conditions or criteria that must be met to achieve Hardy-Weinberg equilibrium. In the first column, list these five criteria. (2.5 marks)

There are five factors that can alter a population’s allele frequency. In the second column, list these five factors so that they match up with the criteria from the first column. (2.5 marks)

In the third column, briefly describe how each of the five factors could alter a population’s allele frequency. (5 marks)

- 3.) Within a population of butterflies, the color brown (B) is dominant over the color white (b). In a study of 15,000 butterflies it was found that 6000 were white and 9000 were brown.
 - a) Based on this information calculate the three genotype frequencies and two allele frequencies for the population. (5 marks)
 - b) In this population, how many butterflies are heterozygous? (1 mark)

- 4.) The whooping crane (*Grus americana*) is the tallest bird in North America, standing almost 1.5 m in height, with a wingspan of up to 2.5 m. While populations of “whoopers” were never large, their numbers declined rapidly in the early 1900s from hunting and habitat destruction due to agriculture. In 1941, only about 21 wild whooping cranes were left in the world—15 migrating birds that nested in the Wood Buffalo National Park of the Northwest Territories and six non-migrating birds that died in a storm in 1949. In the 1940s, various agencies in Canada and the United States of America joined together in an effort to save the birds from extinction.

Wildlife refuges and national parks now protect the whooping crane’s natural summer breeding area in the Northwest Territories and wintering grounds in coastal Texas. Captive breeding programs have been established in some zoos (including the Calgary Zoo). Other flocks have been established in Florida (non-migratory) and Wisconsin (migratory). By the winter of 2008/2009, the whooping crane population had climbed to 534 captive and wild birds, 247 of which nested in Wood Buffalo National Park. All the Wood Buffalo birds today are descended from the 15 migratory birds of 1941.

Conservation efforts are hampered by a number of factors. About 15 percent of eggs laid in the wild are infertile, possibly as a result of inbreeding. Disease is a problem in some captive breeding populations. Severe climatic events, including hurricanes in Texas and late-spring blizzards in the Northwest Territories breeding grounds, can lead to increased mortality. Predation of newly hatched chicks is always a threat. Power lines and cell towers pose hazards during migration. Habitat disturbance in the Texas wintering grounds is an ongoing concern due to shipping and oil exploration and development. While their numbers have increased through conservation efforts, whooping cranes will continue to be vulnerable due to the small population size.

- a) Whooping cranes are an example of an endangered species that has passed through a population bottleneck. Explain how a population bottleneck can alter the genetic variation in the gene pool of a species. (2 marks)
- b) Describe the effect of the population bottleneck on the potential of the whooping cranes to adapt to environmental changes and evolve. (2 marks)
- c) How could the population bottleneck affect the ability of the whooping cranes to recover from near extinction? (2 marks)
- d) Why should we protect and conserve an endangered species? (1 mark)

Appendix G3**Student Work Samples: Assignment 1**

- 4.) a) fittest means that the people that are most adapted are the ones that are going to survive. Not all these genes will be affected with tuberculosis.
- b) multi-drug resistant bacteria would be an example of physiological adaptation because the multi-drug is causing a sickness from its microbes.
- c) Natural selection led to changes in population because of adaptation they had to overcome to survive. Everything around them is changing so they have to as well.

This question earned the following marks:

4a) 1 out of 2 marks

b) 1 out of 2 marks

c) 0.5 out of 2

4 a) In terms of multi-drug resistant bacteria causing tuberculosis, "survival of the fittest" means the traits that are selected for. The bacteria that are most likely to survive are the ones that are resistant to multiple antibiotics; these resistant bacteria that are more likely to survive and reproduce would be considered the "fittest".

b) Multi-drug resistant bacteria would be an example of a physiological adaptation. A physiological adaptation is a change in an organism's metabolic processes that allows it to survive in its environment. The resistant bacteria would be classified as a physiological adaptation because the bacteria has changed how it reacts/processes the antibiotics in order to survive.

c) Since the multi-drug resistant bacteria are better adapted, they are more likely to reproduce. This trait is naturally selected for and is passed on to the generation, causing a directional adaptation; this will mean more of the population will be resistant.

This question earned the following marks:

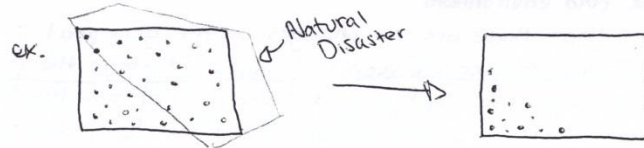
4a) 2 out of 2

b) 2 out of 2

c) 2 out of 2

4

④ a) A natural disaster or human interference eliminates the majority of the population leaving few survivors.



b) Now there are less cranes and there are mostly recessive alleles left. The dominant and recessive allele will have to mate and hopefully have heterozygous or dominant offspring. The recessive allele also may have to migrate to a better environment

c) They would have to mate and make dominant or heterozygous offspring

d) So that we don't have a species die off that we will just end up telling stories to our grandchildren.

This question earned the following marks:

4a) 1 out of 2

b) 0.5 out of 2

c) 0 out of 2

d) 0 out of 1

- 4a) The bottleneck effect explains that when a natural disaster or human interference leaves only a few surviving individuals in a population, the allele frequency of this reduced population may not reflect the ^{allele} frequency of the original population. So, the frequency of one allele is left disproportionately high. It is this allele that ends up being the most likely to be passed on to the next generation.
- b) Bottleneck effect decreases allele variation in a population. Therefore, the small population is less likely to be able to adapt to the changing environment.
- c) The Bottleneck effect would decrease a population's ability to recover from near extinction. This is because without conservation efforts, the small population is vulnerable to hunting, predators, natural disasters, and human interference.
- d) We should protect and conserve an endangered species because the species could play a crucial role in its environment (e.g. if it is a predator, it prevents overpopulation of its prey's species, if it is prey, it is a crucial food source for another species).

This question earned the following marks:

4a) 2 out of 2

b) 1.5 out of 2

c) 1.5 out of 2

d) 1 out of 1

Appendix G4**Unit Test****Evolutionary Theory and Biodiversity Unit Test**

Name: _____

Date: _____

Part I - Multiple Choice: Circle the letter that best completes each statement. One mark each.

1. The Kaibab squirrel lives on the north side of the Grand Canyon and the Albert squirrel lives on the south side. Even though these two populations are only miles apart, their gene pools are kept isolated by
 - a. hybrid infertility
 - b. geographic isolation
 - c. ecological isolation
 - d. altered isolation

2. A population of deer was threatened with overpopulation until cheetahs were imported. After a couple of years there were fewer deer but the average running speed of the deer had increased. This is an example of:
 - a. inheritance of acquired characteristics
 - b. induced mutation
 - c. genetic drift
 - d. natural selection

3. The incorrect theory that “organisms can modify their bodies through use or disuse of parts, and that these modifications can be passed on to their offspring” was formulated by
 - a. Darwin
 - b. Aristotle
 - c. Lamarck
 - d. Lyell

4. Which of the following statements is true?
 - a. A long distance runner will produce gametes with good genes for running because their bodies are in such good physical condition
 - b. Exercise can have an effect on genes
 - c. What a person does during their life can have no effect on their genetic makeup other than random genetic changes from exposure to chemicals or radiation
 - d. Cutting the tails off mice for 100 generations will result in a strain of mice with genes for short tails.

5. The movement of genes into and out of a gene pool is called
 - a. random mating
 - b. non-random mating
 - c. migration
 - d. direct evolution

6. The change in allele frequencies of a population due to chance processes is called
 - a. gene flow
 - b. mutation
 - c. genetic equilibrium
 - d. genetic drift

7. Which of the following statement about evolution is false?
 - a. individuals evolve
 - b. populations evolve
 - c. an entire species evolves
 - d. evolution involves a change of frequency of alleles in the gene pool

8. If within a large population no mutations occur, no migration occurs, all mating are random and each individual has an equal chance of reproducing, which of the following will probably happen?
 - a. Extinction will occur
 - b. Natural selection will occur at the normal rate for that species
 - c. A change in allele frequency will lead to rapid evolution
 - d. No evolution will occur

9. You are studying leaf size in a natural population of plants. The second season is particularly dry and the following year the average leaf size in the population is smaller than the year before. But the amount of overall variation is the same and the population size hasn't changed. You've done experiments that show that small leaves are better adapted to dry conditions. What has occurred?
 - a. directional selection
 - b. stabilizing selection
 - c. disruptive selection
 - d. genetic drift

10. Two species of garter snakes live in the same geographic area. One mainly lives in water and the other mainly on land so that they rarely encounter each other and do not interbreed. This is an example of what type of genetic isolation?
 - a. geographical isolation
 - b. niche differentiation
 - c. altered behavior
 - d. altered physiology

11. Which combination of characteristics in a population would provide the greatest potential for evolutionary change?
 - a. small population, few mutations
 - b. small population, many mutations
 - c. large population, few mutations
 - d. large population, many mutations

12. Darwin collected 13 distinct species of finches from the Galapagos Islands, where the different finches were unique to the various islands. Darwin went on to suggest that each island had its own species of finch because
 - a. Each species flew over from South America at the same time and settled on islands for which they were most suited.
 - b. Each species flew over from South America independently of one another at different times and settled on islands for which they were best suited.
 - c. Multiple birds of one species flew over from South America and landed on each of the islands. Over time, the birds adapted to their environment and evolved into new species.
 - d. The different species were there from the beginning of life on the islands.

13. Sometimes humans breed plants or animals based on traits or alleles that the breeder wants to pass on to the next generation thereby increasing their frequency. This is called _____ and is based on _____.
 - a. natural selection; non-random mating
 - b. natural selection; random mating
 - c. artificial selection; non-random mating
 - d. artificial selection; random mating

14. Which of the following is not included as one of the conditions that must be met under the Hardy-Weinberg Principle?
 - a. Genetic mutations cannot occur
 - b. Gene flow must be allowed
 - c. The population must be very large
 - d. All reproduction must be based on random mating
 - e. Natural selection cannot take place

Section II - Short Answer: Answer the following questions in the space

provided. Mark values are given at each question.

(4) 1. Three types of adaptations that species may develop are structural, behavioral and physiological. Describe two of these, including one example of each to strengthen your descriptions. Be sure to identify how the example would make the organism more fit for their environment.

Adaptation	Description	Example

(4) 2. There are five major **causes of evolutionary change or genetic variation**. They are large population size, mutations, genetic drift, gene flow and non-random mating. Explain, with the use of an example, how any three of these allow for genetic variation.

(4) 3. A population of grasshoppers in the Kansas prairie has two color phenotypes, green and brown. Typically, the prairie receives adequate water to maintain healthy, green grass. Assume a bird that eats grasshopper's moves into the prairie.

a) How will this affect natural selection of the grasshoppers? How might this change in a drought year?

b) Which type of natural selection is occurring in this scenario? (directional, stabilizing or disruptive). Explain your answer.

(4) 4. Define gradualism and punctuated equilibrium.

Does Darwin's theory of natural selection support the theory of gradualism or punctuated equilibrium? Explain your answer.

(3) 5a) In paragraph form, outline the voyage Darwin took, the observations he made, the information he gathered and the struggle he faced with his religious beliefs.

(3) b) Name and explain briefly the six points of Darwin’s theory of Natural Selection.

6. A population of 2000 frogs was tracked for their red spots. Spots are dominant over no spots.

It was found that in the population, 70% of the frogs had spots.

- a) Assuming that the population has reached a relatively stable equilibrium, calculate the allele and gene frequencies within the population. Show your calculations and summarize the answers in the chart provided. (5)
- b) Calculate the number of alleles of each type in the population of 2000. Show your work and summarize the answers in the chart provided. (1)
- c) Calculate the number of frogs in the population of 2000 that will have each of the three genotypes. Show your work and summarize the answers in the chart provided. (1)

Summarize Results:	Allele for Spots	Allele for No Spots	Homozygous Dominant	Heterozygous	Homozygous Recessive
Frequency					
Number of Frogs in Population					

- d) If you observed this population of frogs 100 years later, explain how you could determine whether or not the species has evolved. (1)

Appendix H

Ethics Approval Certificate



Research Ethics and Compliance
Office of the Vice-President (Research and International)

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Fax +204-269-7173

APPROVAL CERTIFICATE

April 10, 2014

TO: Joyce McCallum (Advisor B. McMillan)
Principal Investigator

FROM: Lorna Guse, Chair
Education/Nursing Research Ethics Board (ENREB)

Re: Protocol #E2014:019
"Using Case Study Instructional Methodology in High School Biology: Its Effect on Cognitive Engagement and Critical Thinking Skills"

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement (2). **This approval is valid for one year only.**

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- If you have funds pending human ethics approval, please mail/e-mail/fax (261-0325) a copy of this Approval (identifying the related UM Project Number) to the Research Grants Officer in ORS in order to initiate fund setup. (How to find your UM Project Number: <http://umanitoba.ca/research/ors/mrt-faq.html#pr0>)
- if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/orec/ethics/human_ethics_REB_forms_guidelines.html) in order to be in compliance with Tri-Council Guidelines.

Appendix H1**Consent Form For Superintendent**

Name and Address of Superintendent:

Date:

Dear (Name of Superintendent),

I am writing to request permission to conduct an action research study with my Grade 12 Biology students at _____ Collegiate in _____ School Division. My colleague, _____, will be helping in this study as he is teaching a second section of Grade 12 Biology. This will allow for a control group and an experimental group in this research study. The study is entitled, "Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills."

The purpose of this research study is to determine if students will develop critical thinking skills and be more cognitively engaged in the biology curriculum with the use of case study instructional methods. This study will be conducted during the second semester of this school year (March to June 2014). This will be one of a few teaching strategies used to teach the regular Grade 12 Biology curriculum.

There are several different forms of data collection that will occur throughout the units of study.

This data will be confidential and anonymous until the end of the semester when final marks have been submitted to the office. Participating students work will be anonymous during data collection.

There are no risks to the participants of this study. The benefits may be that the students are exposed to a new teaching method that allows them to link content knowledge to authentic real life situations.

Participation is 100% voluntary and the participants can withdraw at any time throughout the semester, without penalty. Signed consent will be obtained from the parents and students that wish to participate in the study.

If you are willing to give your permission for this study, please sign and date below.

Signature: _____

Date: _____

Yours in Education,

Joyce McCallum

mccallu5@umanitoba.ca

204-822-4425

Professor Barbara McMillan

University of Manitoba

204-474-9036

Barbara.mcmillan@umanitoba.ca

Appendix H2**Consent Form For Principal**

Name and Address of Principal:

Date:

Dear (Name of principal),

I am writing to request permission to conduct an action research study with my Grade 12 Biology students at _____ Collegiate. My colleague, _____, will be helping in this study as he is teaching a second section of Grade 12 Biology this semester. This will allow for a control group and an experimental group in this research study. The study is entitled, "Using Case Study Instructional Methodology in High School Biology: It's Effect on Cognitive Engagement and Critical Thinking Skills."

The purpose of this research study is to determine if students will develop critical thinking skills and be more cognitively engaged in the biology curriculum with the use of case study instructional methods. This study will be conducted during the second semester of this school year (March to June 2014). This will be one of a few teaching strategies used to teach the regular Grade 12 Biology curriculum.

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There are no risks to the participants of this study. The benefits may be that the students are exposed to a new teaching method that allows them to link content knowledge to authentic real life situations.

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If you are willing to give your permission for this study, please sign and date below.

Signature: _____

Date: _____

Yours in Education,

Joyce McCallum

mccallu5@umanitoba.ca

204-822-4425

Professor Barbara McMillan

University of Manitoba

204-474-9036

Barbara.mcmillan@umanitoba.ca

Skolnick, R. (2009). *Case study teaching in high school biology: Effects on academic achievement, problem solving skills, teamwork skills, and science attitudes.* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (Accession Order No. AAI 3365623)

Appendix I

Rubric for Assignments

Names: _____ Date: _____

Category	Beginning	Developing	Accomplished	Advanced
Presentation	Student – omits argument misrepresents or excludes data/information draws faulty conclusions	Student – Misconstructs arguments Generalizes issues or ideas Presents few options Overlooks key information	Student – Argues clearly Identifies issues or ideas Suggests solutions Incorporates information	Student – Argues succinctly <i>Discusses issues or ideas thoroughly Clearly justifies decision</i> Assimilates information
Subject Knowledge	Student – doesn't understand information. directly restates information from sources	Student – Begins thought process Some information is inaccurate.	Student – is comfortable with information can answer most of the question or questions.	Student – is very comfortable with information and/or provides more than the required information. <i>Scientific concepts are accurate.</i>
Interpretation	Student – fails to question information <i>misses major content</i> detects no inconsistencies	Student – identifies some questions has basic content states some inconsistency	Student – Asks insightful questions Detects bias <i>Recognizes content</i> and identifies inconsistencies	Student – <i>Analyzes insightful questions</i> Refutes bias Critiques content Examines inconsistencies
Analysis and Evaluation	Student – <i>Fails to draw conclusions Overlooks key ideas Omits information</i>	Student – Identifies some form of a conclusion <i>Paraphrases data</i>	Student – Formulates conclusions Recognizes arguments Notices differences Evaluates data Seeks out information	Student – Examines conclusions <i>Used reasonable judgment</i> Synthesizes data Views information critically

Rubric source from: CSU Fresno, <http://www.csufresno.edu/cetl/assessment/CTScoring.doc>

Appendix J

Questions for Cognitive Engagement

The following is a list of questions that the students will be asked in a semi-structured format.

The purpose is to allow the students to have the opportunity to express or elaborate on their views about the course and their view of engagement.

Questions:

1. Complete this statement: *I do work in class because.....*
2. If you are engaged or interested in a task, what would someone see you doing to show your interest/engagement with the task? (What do you look like when you are interested in what you are doing?) OR What would you look like if you are so involved in the activity that you forgot everything around you?
3. How do your actions/responses change in a situation if you go from a non-engaging activity to an engaging one (for you)?