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# Making Online Learning Personal: Evolution, Evidentiary Reasoning, and Self-Regulation in an Online Curriculum

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MAKING ONLINE LEARNING PERSONAL:  
EVOLUTION, EVIDENTIARY REASONING, AND SELF-REGULATION  
IN AN ONLINE CURRICULUM

by

Robert B. Marsteller

Presented to the Graduate and Research Committee  
of Lehigh University in Candidacy for the Degree of

Doctor of Philosophy

in

Teaching, Learning, and Technology

Lehigh University

April 2017

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## Dissertation Approval Form

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## **Dedication**

This work is dedicated to my wife Katie  
who has walked with me through this journey.

## **Acknowledgements**

Preparing this dissertation has been the culmination of a long period of growth and learning. I have been fortunate to have the support and guidance of so many wonderful people.

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## Abstract

An online curriculum about biological evolution was designed according to the *Promoting Evidentiary Reasoning and Self-regulation Online* (PERSON) theoretical framework. PERSON is an attempt to develop online science instruction focused on supporting evidentiary reasoning and self-regulation. An efficacy study was conducted with 80 suburban high school biology students using a design-based research approach to develop a curriculum to promote biological evolution understandings, evidentiary reasoning, and self-regulation. Data sources and instruments included (1) the Biological Evolution Assessment Measurement (BEAM); (2) the modified *Motivated Strategies for Learning Questionnaire* (MSLQ); (3) discussion forum posts; (4) formative assessments of evidence based reasoning; (5) *Prediction, Monitoring, and Reflection* forms (PMR); (6) the *Online Instruction Questionnaire*; and (7) field notes. Findings revealed that BEAM posttest scores were significantly greater than pretest scores for items designed to measure biological evolution content knowledge and evidentiary reasoning. Students tracked in a lower level biology course showed improvement in biological evolution understandings and evidentiary reasoning. It was found that performance on daily evidentiary reasoning tasks strongly predicted BEAM posttest scores. However, findings revealed that students did not meet local standards for performance on items designed to measure evidentiary reasoning. Students expressed a variety of opinions about their learning experiences with the online curriculum. Some students expressed a definite preference for traditional learning environments, while others expressed a definite preference for online learning. Self-regulatory ability did not significantly predict BEAM gain scores. Further, self-regulatory ability was not demonstrably improved as a result of this intervention. Implications for designing science

instruction in asynchronous online learning environments to support evidentiary reasoning and self-regulation are discussed.

## CHAPTER 1: INTRODUCTION

### **Growth of Online Learning For Students That Have Not Been Successful in Traditional Learning Environments**

The number of K-12 students enrolled in online courses has increased substantially over the past decade (Barth, Hull, & St. Andrie, 2012; Horn & Staker, 2011; Queen, Lewis, & Coopersmith, 2011). Predictions for the future expect as many as 50% of all high school courses will be delivered online (Christensen, Horn, & Johnson, 2008). However, according to a report by the Evergreen Education Group, online courses disproportionately serve students that have been unsuccessful in traditional classroom settings (Watson, Murin, Vashaw, Gemin, and Rapp, 2012).

Research began focusing on online learning in the early 1990's (for reviews, see Black, 2007; Feasley & Bunker, 2007). There has been a good deal of research comparing online learning to "traditional" pedagogies, most of which have found no significant differences in learning outcomes between these two different learning environments (Allen et al., 2004; Bediako Asare, 2014; Beebe, Vonderwell, & Boboc, 2010; Bernard et al., 2004; Cavanaugh, Barbour, & Clark, 2009; Pentina & Neeley, 2007; Stack, 2015; Summers, Waingandt, & Whittaker, 2005). Similar learning outcomes indicate that research across learning environments may be mutually applicable. Consequently, designers for online learning environments can make use of research conducted in traditional classroom environments and may use similar metrics for predicting academic success.

Given the comparable nature of learning outcomes in traditional and online learning environments, and the disproportional representation of students that have not succeeded in traditional classrooms learning online, attention must be paid to how best to educate this



population. Several studies have found that asynchronous online learning environments were particularly effective for students that have difficulties in traditional classrooms such as ESL learners (Bassett, 2011), students with learning disabilities (Graves, Asunda, Plant, & Goad, 2011), or students with a general reluctance to participate in face-to-face discussions (Al-Salman, 2009; Bassett, 2011; Gerbic, 2010). Asynchronous online learning environments allow learners increased time for reflection and thoughtful participation in coursework (Giesbers, Rienties, Tempelaar, & Gijsselaers, 2014; Younghee, & Reeves, 2008). However, it has also been argued that asynchronous learning environments require more independence from learners than comparable synchronous environments (Giesbers et al., 2014). Because the same students that benefit from the unique affordances of asynchronous online learning environments often lack the skills to learn independently, special attention must be paid to supporting learner independence (Nandi, Hamilton, & Harland, 2012).

Successful students have strategies to learn independently; less successful learners often lack these strategies (Hodges, & Kim, 2010; Jakubowski & Dembo, 2004). These strategies have been collected together under the umbrella of self-regulated learning (SRL). Kitsantas and Zimmerman (2009) defined self-regulation of learning as the degree that students are metacognitively, motivationally, behaviorally, and actively responsible for their learning processes. SRL includes awareness of learning needs, the use of effective learning strategies, and the ability to evaluate learning outcomes (Pata, 2009). Previous research had found that support for self-regulation must make learners actively engage in the process of self-regulation (Al-Rawahi & Al-Balushi, 2015; Chang, 2005; Chang, 2007; Hodges & Kim; 2010). While this research agrees conceptually, there is as of yet no clearly defined set of best practices for supporting self-regulation in online learning environments.

Developments in research about effective instruction in online learning environments have been concurrent with efforts to reform science instruction for K-12 students. The *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) integrate discipline specific core content, scientific practices, and crosscutting concepts. Core content are scientific facts and concepts that students are expected to know (eg. “genetic information provides evidence of evolution” or “traits that positively affect survival are more likely to be reproduced”). Scientific practices are methods scientists use to understand the natural world (e.g. “analyzing and interpreting data” and “using computational thinking”). Crosscutting concepts connect various scientific fields to form a cohesive body of knowledge (e.g. “patterns” and “cause and effect”). The NGSS provide performance expectations of what students should be able to do as a result of instruction (NGSS Lead States, 2013; Quattrone, 2013). While there are many crosscutting concepts and scientific practices, this research will focus on a critical skill that benefits students’ learning in multiple academic domains.

An example of a scientific practice is evidentiary reasoning (NGSS Lead States, 2013; NRC, 2012). Evidentiary reasoning is the process of collecting and organizing information to support inferences (Pellegrino, Wilson, Koenig, & Beatty, 2014). Previous research has found that K-12 students lack skills associated with evidentiary reasoning (Marsteller & Bodzin, 2015; Schalk, van der Schee, & Boerman, 2013). Further, students do not seem to have many opportunities to develop those skills (Biggers, Forbes, & Zangori, 2013). Consequently, it is necessary to create instruction that promotes evidentiary reasoning.

### **A Framework to Support Successful Online Learning**

The *Promoting Evidentiary Reasoning and Self-regulation Online* (PERSON) theoretical framework is an attempt to develop online science instruction focused on supporting evidentiary

reasoning and self-regulation. Research has identified six common characteristics of effective online science instruction: *inquiry-based instruction* (Hickey, Kindtfield, Horwitz, & Christie, 1999; Geier et al., 2008; Lynch, Kuipers, Pyke, & Szesze, 2005); *scaffolding* (Lee, Linn, Varma, & Liu, 2010; Linn, Clark, & Slotta, 2003; Quintana et al., 2004; Resier, 2004); *methods of communication* (Chang, Hurst, & McLean, 2015; Crawford-Ferre & Wiest, 2012); *discussion & reflection* (Crawford-Ferre & Wiest, 2012; Dzubinski, 2014; Linn, 2003; Linn et al., 2003; Maddix, 2012; Quintana et al., 2004; Reiser, 2004; and Vonderwell & Zachariah, 2005); *visualizations* (Linn et al., 2003; Lee et al., 2010); and *simulations & modeling* (Beckham & Watkins, 2012; Linn, 2003; and Quintana et al., 2004). PERSON is a design framework based on these research-based best practices and a synthesis of Bandura's (1977) social cognitive theory and Lave and Wenger's (1991) situated learning theory. Additionally, the PERSON framework's approach to addressing the motivational needs of students is informed by the ARCS design model.

Social learning theory and situated learning theory compliment each other by focusing on the interactions learners have with each other and members of communities of practice. As learners engage in legitimate practices within a field, they are able to synthesize knowledge with existing cognitive structures that provide relevance for their learning. The ARCS instructional design model analyzes motivational needs of learners based on four dimensions that are attention (A), relevance (R), confidence (C), and satisfaction (S) (Keller, 1999). To develop these cognitive structures, eight key elements have been included in the design of PERSON. The four dimensions of motivation identified by the ARCS model have been applied to key elements of PERSON. The key elements include: *Foundational Knowledge*; *Simulation Study*; *Analyze and*

*Extend; Case Study; Social Discourse; Scaffolding of Self-regulation; Scaffolding Evidentiary Reasoning; and Evaluation.*

Facts and basic concepts are initially presented in the *Foundational Knowledge* section. The initial presentation attempts to gain learner's attention, as prescribed by the ARCS model. This is followed by inquiry-based exploration in the *Simulation Study*. The *Analyze and Extend* element provides scaffolded problem solving and prepares students to engage with scientific practices in the *Case Studies*. Students use an asynchronous discussion forum to exchange ideas throughout the curriculum as a method of promoting *Social Discourse*. These four elements (*Simulation Study, Analyze and Extend, Case Studies, and Social Discourse*) have been created to be as relevant as possible to high school age learners. Examples and activities are intended to relate in some way to student's lives and to account for the second dimension of the ARCS model. Students receive regular and consistent *Scaffolding of Self-Regulation* to develop skills necessary to learn independently. The skills of *Evidentiary Reasoning* are scaffolded and practiced continuously. The scaffolded elements of PERSON address learners' needs for confidence, according to the ARCS model. Providing appropriate support for learners engaging in complex tasks will maintain student motivation. *Evaluation* provides formative and summative feedback. Students should feel a high degree of satisfaction with improved performance from the pretest to posttest evaluation measurements. Providing students with a sense of successful accomplishment is consistent with the fourth dimension of the ARCS model.

The eight key elements of the PERSON framework are interrelated and reliant on each other to engender successful learning outcomes. As such, it is necessary to evaluate the PERSON framework holistically within a learning context. The PERSON framework is being evaluated as part of an iterative process used to design a specific content unit appropriate for

high school biology students within the recommendations of the NGSS. The current iteration of this research has been modified in response to outcomes from a previous initial prototype implementation study (Marsteller & Bodzin, 2015).

### **Statement of Purpose**

The purpose of this study is to continue a process to determine the effectiveness of an online curriculum to promote biological evolution understandings, evidentiary reasoning, and self-regulation. In order to make a contribution to the knowledge base, this study will evaluate the effectiveness of a new theoretical framework for designing an online curriculum.

The majority of K-12 students enrolled in online courses are seeking credit recovery after they have failed a traditional course (International Association for K-12 Online Learning [iNACOL], 2013; Queen et al., 2011; Watson et al., 2012). Students that are not successful in traditional learning environments have specialized instructional needs (Hodges, & Kim, 2010; Jakubowski & Dembo, 2004). Consequently, there is a need to tailor online learning environments to the unique needs of these academically unsuccessful students.

All learners differ in their levels of perseverance, readiness to avail themselves of learning opportunities, and aptitude for particular content matter (Zimmerman & DiBenedetto, 2008). These common characteristics can be organized into descriptive sets of characteristics identified as self-regulated learning (SRL) and motivation. Differences in learning outcomes for students in online environments can be attributed to variations in motivation and self-regulation (Giesbers et al., 2014).

SRL describes students' abilities to actively monitor and control cognition, motivation, and interactions with learning environments (Dembo & Eaton, 2000; Kitsantas & Zimmerman, 2009). Components of self-regulation such as motivation (Archambault et al., 2010), satisfaction

(Levy, 2007), and self-efficacy (Astleitner & Hufnagl, 2003; Hodges & Kim, 2010) have been found to positively correlate with successful learning outcomes for students in online learning environments. Curriculum designs for online learning that intentionally support SRL have been found to promote successful learning outcomes (Al-Rawahi & Al-Balushi, 2015; Archambault et al., 2010; Chang, 2007; Zimmerman and Tsikalas, 2005).

Motivation to learn is a key feature of self-regulation. Students' that are not typically successful in traditional classroom settings experience motivation as a primarily extrinsic quality (Giesbers et al., 2014; Matuga, 2009; Rakes & Dunn, 2010). Extrinsically motivated students are not necessarily less capable of academic tasks than their intrinsically motivated peers (Zimmerman & DiBenedetto, 2008). However, extrinsically motivated students benefit from consistent motivational support. Learning environments can be intentionally designed to support motivation (Kim, 2012; Pata, 2009; Rakes & Dunn, 2010). Research by Giesbers et al. (2014) demonstrated that learning environments with support for student autonomy benefit student engagement.

In addition to the development of effective online instruction, science education reform creates additional challenges for curricular design. The *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) is a recent science education reform document that focuses on content knowledge, scientific practices, and broad conceptual understandings. The NGSS are a performance-based set of expectations (NGSS Lead States, 2013; Quattrone, 2013).

While the NGSS has identified a number of scientific practices, previous research has found that K-12 students are not skilled at the scientific practice of evidentiary reasoning (Marsteller & Bodzin, 2015; Schalk et al., 2013). Evidentiary reasoning is the collection and

organization of information in the support of inferences (Pellegrino et al., 2014). Consequently, it is necessary to create instruction that promotes evidentiary reasoning.

The PERSON framework is based on research-based best practices and a synthesis of Bandura's (1977) social cognitive theory and Lave and Wenger's (1991) situated learning theory that has been informed by the ARCS instructional design model (Keller, 1999). Eight design elements of the PERSON framework interact to promote content knowledge, the scientific practice of evidentiary reasoning, and self-regulation. The PERSON framework has been applied to the design of an NGSS-aligned unit on biological evolution for high school biology students.

This study will use design-based research to further evaluate the effectiveness of the online curriculum design and implementation approach. The design of this online curriculum has been revised according to findings from a pilot study. A design-based research approach was chosen because it takes into consideration the variety of factors that may influence effective implementation of a curriculum design (Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003; Tabak, 2004). Pretest and posttest comparisons will be used to measure changes in student understanding and skills as a result of curriculum implementation. Analysis of student discussion forums, a post-implementation survey, and qualitative observations about curriculum implementation will provide context for test outcomes.

### **Research Questions**

This study proposes to compare pretest and posttest performance on measurements of three dependent variables as a result of using an online curriculum. The dependent variables are biological evolution understandings, evidentiary reasoning, and self-regulation.

- 1) Whether and to what extent can an online curriculum promote biological evolution

understandings with students in high school?

- 2) How well does the online curriculum promote students' evidentiary reasoning?
  - 2a) How well does scaffolding promote students' evidentiary reasoning?
- 3) How do students perceive learning experiences using the online curriculum?
- 4) How well does student baseline self-regulatory ability predict success in using the online curriculum?
- 5) How well does the online curriculum promote student self-regulation?

### **Significance of this Study**

Numbers of K-12 students enrolled in online courses continue to increase, especially those students who have not been successful in traditional learning environments (Barth, Hull, & St. Andrie, 2012; Horn & Staker, 2011; Queen et al., 2011, Watson et al., 2012). While there is evidence that students with a history of struggling to succeed academically may benefit from online learning environments, there is a need to actively support their independent learning (Nandi et al., 2012). Further, the challenges of science education reform, such as teaching core content knowledge and scientific practices, must be met in the online learning environments these students will inhabit (NGSS Lead States, 2013). The goal of this study is to evaluate the effectiveness of a new design approach to online instruction aligned with the goals of science education reform and supporting the development of self-regulation skills.

This study explores the ability of online learning environments to support the higher order thinking demanded by science education reform documents. History would suggest that the ambitious goals of science education reform have not been achieved in traditional learning environments. Given the numerous science education reform documents from the past thirty-five years that have drawn attention to the shortcomings of current approaches to science



instruction (Burton & Frazier, 2012), it is possible that the growth of online learning environments represent an opportunity to address these shortcomings. The PERSON framework is an attempt to create a cohesive approach to online learning that emphasizes higher-order thinking aligned with the goals of science education reform.

Further, the independent nature of online learning environments presents a challenge, especially for K-12 students. Self-regulated learning is a suite of skills, each of which may be developed to different degrees within any individual student. All of the skills associated with actively monitoring and regulating one's own learning increase in importance the further a student is removed from a traditional learning environment (Archambault et al., 2010; Giesbers et al., 2014; Rakes & Dunn, 2010). This study has embedded support for self-regulation in the PERSON framework. Previous research has sought to support SRL in online learning environments as an add-on to existing courses. The PERSON framework positions SRL as a key component of the design of instruction.

Every student, regardless of learning environment, deserves to be challenged and supported in a manner that makes those challenges achievable. Online learning environments increasingly serve to educate the students most in need of support to achieve challenging goals. It is unacceptable to warehouse poorly performing students in online courses that neither appropriately challenge nor stimulate them. The PERSON framework attempts to address the need for rich, stimulating online learning that supports learners who may otherwise find themselves struggling in yet another type of learning environment.

## CHAPTER 2: REVIEW OF THE LITERATURE

### Online Teaching and Learning

#### What is Online Learning?

Online learning environments use a suite of web-based tools for procedural and learning elements for instructional delivery. Classroom management and communication tools can be used for submitting assignments, taking attendance, or using email for exchange between students and instructors. Further, online learning includes delivering content via video, podcast, blog, or other web-based media. Students may use online tools such as simulations to apply and practice skills and understandings.

Research examining online learning has expanded its scope commensurate with the growth of online learning in the past twenty years. The literature that has examined online education has grown from an extension of distance education that saw online technologies as an efficient replacement for mail-based correspondence, or distribution of lectures by radio, satellite, or cable TV to the common pedagogical tools online learning has become (Bates, 2014; Bernard et al., 2004; Feasley & Bunker, 2007; Horn & Staker, 2011). The American Center for the Study of Distance Education (ACSDE) first proposed an agenda focusing on research on computer conferencing in 1990 (Black, 2007). The Sloan Foundation began awarding grants to promote online learning in 1993 and found increasing acceptance among educational institutions in subsequent years (Feasley & Bunker, 2007). Online learning has benefitted from the development of the Internet, decreasing costs of digital compression, and the use of Wi-Fi networks that circumvent the need to develop physical infrastructures (Bates, 2014).

## **Types of Online Learning**

Online learning has developed in various forms, including asynchronous and synchronous communication, web-based learning environments, and commercial course platforms. Each of these online learning types is discussed in the subsections that follow.

**Asynchronous online learning.** Asynchronous online learning uses technologies such as Web-based forums and email to allow delayed communication among course participants (Younghee & Reeves, 2008). One of the first examples of asynchronous computer communication in an educational setting was at the University of Illinois where Programmed Logic for Automated Teaching Operations system (PLATO) was developed during the 1970s. PLATO used computers networked to mainframes in the development of many now familiar applications, such as message boards, online tests, email, instant messaging, and remote screen sharing (Smith & Sherwood, 1976). Another early example was at the New Jersey Institute of Technology where locally networked discussion forums were blended with a face-to-face class (Turoff & Hiltz, 1978). Early adopters of online teaching technologies were limited by the need for computing infrastructure such as mainframes and terminals that were not readily available outside of large academic or corporate institutions.

The development of Arpanet in 1982 marked the first time the Internet protocol was used on a network and ushered in new possibilities in broadening the potential for networked communication beyond local networks (Bates, 2014). Through the 1980's the University of Guelph, in Canada, developed CoSy, an off-the-shelf software package that allowed for threaded discussion forums. CoSy was incorporated into courses in Britain's Open University in 1988 (Bates, 2014). From a historical perspective, all of the elements of asynchronous communication

in educational settings were established prior to the launch of the World Wide Web in 1991 (Bates, 2014).

A lack of social connection has been cited as major shortcoming of asynchronous online learning (Giesbers, Rienties, Tempelaar, & Gijsselaers, 2014; Hiltz, 1998). It has been established that students do not intuitively understand how to interact with peers or instructors in asynchronous online learning (Younghee, & Reeves, 2008). Decreased facility with asynchronous interactions may cause learners to contribute less to social discussion both in terms of quality and quantity (Giesbers et al., 2014). However, a literature review conducted by Johnson (2006) to compare student satisfaction with courses using either synchronous or asynchronous text-based communication found outcomes to be equivalent, or to slightly favor asynchronous courses. The strengths of asynchronous communication become more apparent when considering the needs of specialized populations of learners.

While much is made of the social limitations of asynchronous communication, these limitations may allow students that struggle in social settings an opportunity to thrive. Research has found that students who are reluctant to participate in face-to-face discussions report that asynchronous discussions are valuable to their learning satisfaction (Al-Salman, 2009; Bassett, 2011; Gerbic, 2010). ESL learners were identified as a type of learner that could especially benefit from the increased time for reflection and response afforded by asynchronous discussions (Bassett, 2011). Further, students with learning disabilities and ADHD have responded positively to asynchronous discussions used to supplement face-to-face class activities (Graves, Asunda, Plant, & Goad, 2011). Research findings support the idea that the students that can benefit most from asynchronous online discussions are those that are least successful in traditional classroom settings.

Asynchronous communication in online learning offers some unique affordances that are not matched by synchronous counterparts. For example, asynchronous online learning environments allow learners increased time for reflection and consideration of their participation in discussions with instructors and peers (Giesbers et al., 2014; Younghee, & Reeves, 2008). Some educators argue that asynchronous learning environments are more effective at promoting higher order thinking skills (Younghee, & Reeves, 2008). However, it must be conceded that asynchronous learning environments require a greater deal of learner autonomy than comparable synchronous environments (Giesbers et al., 2014). Research by Nandi, Hamilton, and Harland (2012) found that student engagement in asynchronous discourse is not automatic, and requires instructor support. Bassett (2011) analyzed reflections written by student participants using asynchronous discussion forums. The researcher found that students perceived these forums to provide a valuable, inclusive environment; particularly students taking courses that are not in their native language (Bassett, 2011).

**Synchronous online learning.** Synchronous online learning relies on web-based technologies such as video conferencing, live streaming, and online chat software to enable real-time audio and visual communication between instructors and students (Giesbers et al., 2014). The development of synchronous online learning has occurred over the past 25 years. One of the earliest examples of synchronous online learning is the JASON Project, which was founded in 1989 (About JASON, n.d.). The JASON Project utilized web-conferencing to allow K-8 students in classrooms to communicate with scientists around the world as part of a larger, multimedia approach to promoting science (Moss, 2003; Phillips, 2006). The JASON Project is an example of a well-funded, highly developed effort at synchronous online learning that has grown and evolved with developments in Web-based communication technologies.

Within the last ten years researchers surveying the affordances of online learning saw Internet connection speeds as a substantive barrier to synchronous transmission of audio and video content (McGreal & Elliot, 2008). Initial attempts to clarify the nature of synchronous online environments sought to define relevant terminology. One such term is telepresence. Initially, telepresence referred to the ability of a user to remotely manipulate an object (Minsky, 1980). However, this term evolved to encompass a description of the extent to which a user feels present in a virtual environment, rather than a physical environment (Steuer, 1992). Research on telepresence, largely conducted in communication and business fields, has grown to understand immersion in a virtual environment to be a product of the richness of the media and the level of interactivity available to users (Edwards, 2011; Klein, 2002; Steuer, 1992). A study conducted by Faiola, Newlon, Pfaff, and Smyslova (2013) found that telepresence positively correlated with increased student motivation and immersion in learning activities. The development of streaming technologies and peer-to-peer file has opened possibilities for more immersive synchronous learning opportunities (McGreal & Elliot, 2008). That potential has largely been fulfilled in recent years.

**Web-based learning modules.** Web-based learning refers to the delivery of learning materials through a web browser (Tsai and Machado, 2002). The initial development of web-based learning included Learning Management Systems (LMS), sometimes called course management systems. The first LMS, Web course tools (WebCT) was released in 1995 (Bates, 2014; Seepersaud, 2011). Other examples include AuthorWare, Blackboard, Desire2Learn, Director, Moodle, ToolBook, and TopClass (Janicki, & Liegle, 2001; Unal & Unal, 2014). LMSs allow teachers to load and organize dynamic and interactive course content in a central location (Unal & Unal, 2014).

The term *web-based learning module* refers to the use of LMSs to organize course content into components such as lectures, simulations, or problem sets, that guide student learning (Ozer, Kenworthy, Brisson, Cravalho, & McKinley, 2003; Pomales-Garcia & Liu, 2006). Instructors may require a specific, linear order of activities, or may permit learners to explore elements of the module in a nonlinear fashion (Seepersaud, 2011). However, early web-based courses often loaded course material from face-to-face lectures directly to the web without regard to unique online affordances or challenges (Janicki, & Liegle, 2001). Later, attention was given to unique affordances of web-based learning modules such as multimedia interactivity, flexibility of pace, and the ability to collaborate at a distance (Parker & Paker, 2010; Weston & Barker, 2001). Subsequent research has sought to expand the repertoire of web-based learning to include multimedia presentations (Ozer et al., 2003), the development of web-specific design principles (Janicki, & Liegle, 2001), and attention to the effects of web-module design on student learning (Pomales-Garcia & Liu, 2006). Other researchers have argued that the most effective web-based learning modules reduced technical barriers to learning and allowed instructors and learners to focus on content (Weston & Barker, 2001; Unal & Unal, 2014). Web-based learning modules are now a common part of a variety of online learning environments.

**Commercial learning management systems.** Much of the development of LMSs was accomplished by businesses attempting to generate revenue. The most successful commercial course platform to date is Blackboard (Empson, 2012; Green, 2012; Unal & Unal, 2014). Blackboard was founded in 1997, just a few years after WebCT (Bates, 2014; Leibovich, 1999; Unal & Unal, 2014). Rather than individual universities developing their own LMS software, Blackboard was able to develop and sell packages of software around the world (Leibovich, 1999). While other commercial course platforms were developed at that time, many of the most

successful, including Angel and Web CT were acquired by Blackboard to expand market share and increase Blackboard's capabilities (Empson, 2012; Green, 2012; Kennedy, 2009).

Some institutions sought to utilize Open Source LMS options such as Sakai or Moodle (Green, 2012; Unal & Unal, 2014). Open Source LMSs are available at no cost, but do not offer the level of technical support found in commercial systems (Unal & Unal, 2010). Research, including a comparative study of 135 undergraduate students, has found Moodle to be rated as equal or better than Blackboard by users (Unal & Unal, 2014). In response to the growing presence of Open Source LMSs, Blackboard has aggressively expanded into Open Source markets with acquisitions and products of its own (Green, 2012). While the presence of commercial and Open Source LMSs is expanding in university and K-12 settings, it is necessary to discuss how these learning tools are being utilized to interface with students in blended and fully-online courses.

### **An Online Learning Continuum**

Several researchers have attempted to describe the variety of ways online learning occurs in school settings. Allen and Seaman (2013) define a continuum of use for online learning. *Traditional classrooms* use no online technologies. *Online courses* deliver most or all content online and have no face-to-face meetings. *Web facilitated classrooms* may use course management systems or post assignments to web pages. While *blended classrooms* deliver substantial portions of content online.

Barth, Hull, and St. Andrie (2012) draw distinctions between two types of online learning. "Fully online" learning indicates either a single class or an entire virtual school where instruction is entirely online. "Blended learning" indicates a mixture of in-person and online instruction.



Horn & Staker, (2011) define six models that roughly define all online learning as blended, according to previously cited distinctions. The differences between Horn and Staker's models are how online technologies are deployed. The face-to-face driver model is predicated on a physical teacher deploying online learning as needed. The rotation model uses fixed schedules of face-to-face and online learning. The flex model uses online learning as the foundation for instruction, with a physical teacher present to facilitate and provide face-to-face instruction as needed. The online lab model uses exclusively online learning, including an online teacher presence, with students present in a brick and mortar environment where they are supervised by a paraprofessional or someone without relevant content knowledge. The fifth model, called self-blend, allows students to pick and choose individual courses to take remotely online, while other courses are taught according to other models. The final method of deployment is the online driver; in this model students work remotely with an online instructor.

These attempts to define categories of online learning share a common position that online learning is not always distinct from traditional settings. Understanding online learning as part of a continuum of practice makes rigid distinctions between traditional and online learning difficult. If an instructor shows a web-based video or emails a student even once, is that course still traditional? Little value remains for drawing boundaries between learning with or without online tools.

For the purpose of this literature review three categories describing positions along the online learning continuum will be used. In keeping with accepted language, these categories are traditional, blended, and fully online. Traditional learning environments are defined as those with absolutely no online component in instruction, assessment, or communication. Blended learning environments utilize online components for some part or parts of instruction,

assessment, and communication, while other parts are delivered face-to-face without the mediation of online technologies. Fully online learning environments have no face-to-face components in instruction, assessment, or communication and are conducted entirely through the mediation of online technologies. Fully online may refer to individual classes or entire virtual schools. These categories will provide useful terminology for comparing learning environments.

### **Comparing Online and Traditional Learning**

Concurrent with the development of online learning as a tool for distance education has been a wealth of research comparing online learning to “traditional” pedagogies (Allen et al., 2004; Bediako Asare, 2014; Beebe, Vonderwell, & Boboc, 2010; Bernard et al., 2004; Cavanaugh, Barbour, & Clark, 2009; Pentina & Neeley, 2007; Stack, 2015; Summers, Waingandt, & Whittaker, 2005). In a meta-analytical summary of quantitative studies comparing distance and traditional methods of instruction, Allen et al. (2004) detected a slight improvement in exam scores and course grades for online students compared to their peers in traditional classrooms; however, statistical variations caused the authors to conclude only that distance technologies could not be demonstrated to cause a clear decline in effectiveness compared to traditional classroom practices. Further meta-analysis of literature comparing delivery methods conducted by Bediako Asare (2014) found no significant difference in achievement between methods, with the author arguing against research that continued to focus on comparing online and traditional learning environments. A third meta-analytic comparison conducted by Bernard et al. (2004) found overall effect sizes between learning environments to be “essentially zero” between online and traditional learning environments, while conceding wide variability within the data.

Additional meta-analyses by Cavanaugh, Barbour, and Clark (2009) found that outcomes comparing online and traditional pedagogies varied widely, with much of the literature dedicated to promoting the potential of online learning. Further research by Summers et al. (2005) and Stack (2015) compared performance between media while controlling for instructor, course design and content. Summers et al. (2005) found no significant difference in final grades for an undergraduate statistics course, though this same research did find that students in the online course were significantly less satisfied with their learning experience. Stack (2015) compared students studying criminology at the undergraduate level, finding no significant difference in either final exam scores, or course evaluations, which could approximate student satisfaction. Beebe et al. (2010) compared assessment practices in seven courses at two different colleges using a phenomenological approach, concluding that online courses benefit from including best assessment practices from traditional courses, especially informal, formative assessments.

Finally, when considering what kinds of students take courses in different environments, Pentina and Neeley (2007) sought to identify pertinent factors from a marketing perspective that would allow institutions to attract and retain more online students. The authors found no significant differences in demographics or perceptions of time pressures between students in different learning environments. The only significant difference found was that students in traditional classes are significantly more skeptical of the educational value and effectiveness of online courses (Pentina & Neeley, 2007). As a result of the establishment of comparability between different learning environments, scholarship on distance education has shifted its focus to within group comparisons since the beginning of the 21<sup>st</sup> century (Black, 2007).

**Advantages of online learning.** Studies have examined the differences between learning outcomes for students in online and traditional instruction environments and found no difference

in students' motivation or achievement between these environments (Stack, 2015; Summers et al., 2005; Wilson & Allen, 2001). This is encouraging in that it provides a degree of transfer between established classroom practices and online environments. Designers of online learning environments can rely on the research conducted in traditional classroom environments without having to create a unique pedagogical foundation for online learning. Consistent with these findings, Wilson and Allen (2011) further found that, among the college students that served as their subjects, cumulative GPA was the best predictor of course grades in either face-to-face or online learning environments. Similar metrics for predicting success may be useful.

**Disadvantages of online learning.** The implications of these same studies (Stack, 2015; Summers et al., 2005; Wilson & Allen, 2001) may be considered discouraging if it is expected that students that have failed in traditional learning environments will be subject to the same conditions and obstacles in online environments. However, it can be argued that many well-established methods of educating struggling learners, such as the Attention Relevance Confidence and Satisfaction (ARCS) design model (Keller, 1999), are not regularly implemented in face-to-face classrooms. As such, online learning environments may offer opportunities for struggling students to experience pedagogy designed for their benefit.

### **Learning Theories that Support Online Learning**

Current pedagogical perspectives promote a cognitive view of learning (Ormrod & Davis, 2004). In contrast to behavioral perspectives that restrict research and theory to empirical observations, cognitive theory assumes that observations of behavior can allow researchers to make inferences about internal mental processes (Ormrod & Davis, 2004; Reisberg, 1997). Jean Piaget (1952) promoted the idea that children are motivated learners that construct understanding of their environment through interaction. Lev Vygotsky (1978) built on Piaget's ideas by

proposing that interactions with peers and knowledgeable other people, the social environment, are the foundation of complex mental processes. Learners observe and make sense of the behavior of others, developing models for problem solving in the process.

Constructivism is a perspective on cognitive learning theory that accounts for the learning processes described by Piaget and Vygotsky (Ormrod & Davis, 2004). Constructivism assumes that learners actively organize and make sense of information in idiosyncratic ways (Hmelo-Silver, Duncan, & Chinn, 2007; Marshall, 1992; Mayer, 1996; Prawat, 1993). Because constructivism assumes active participation in learning, it is necessary to incorporate theory that accounts for motivation for learning. Keller's (1999) ARCS model is a well-established theory about motivation in an instructional context.

### **ARCS Model**

Keller (1999) established an instructional design model that provides a complex perspective on motivation. The ARCS motivational process analyzes motivational needs of learners based on four dimensions that are attention (A), relevance (R), confidence (C), and satisfaction (S). These facets account for various reasons that students may lack motivation for a given subject, course, or activity, while providing a framework for designing learning environments that support student needs. The validity of the ARCS model has been established by deriving its principles from the motivational research literature and from tests for predictive and discriminative validity (Keller, 2008). Keller (2008) contended that the principles of the ARCS model apply in all learning environments, including online learning environments. Green (2012) proposed that the ARCS model could be especially useful in designing learning in asynchronous online environments, where learner motivation is often difficult to maintain.

Further, Gormley, Colella, and Shell (2012) contended that the ARCS model could be used to intentionally support student achievement in online learning environments.

### **Growth of Online Learning in High School**

At the beginning of the millennium, 45,000 K-12 students were enrolled in online courses. By 2009 the number of K-12 students enrolled in online courses had grown to 3 million, with a substantial increase in blended learning environments (Horn & Staker, 2011). In the period from 2009-10, 55% of public school districts had students enrolled in online courses, almost all of which were high school students (Queen, Lewis, & Coopersmith, 2011). Forty states have created online learning policies, while 30 states and the District of Columbia have created virtual schools (Barth, Hull, & St. Andrie, 2012). As of 2014-15, 26 states have fully online charter schools, with approximately 200,000 students enrolled (Watson, Pape, Murin, Gemin, & Vashaw, 2014). In their book, *Disrupting Class*, Christensen, Horn, and Johnson (2008) predicted that 50% of all high school courses will be delivered online by 2019.

### **Who is Taking Classes Online?**

The fastest growing online programs are those offered by school districts specifically for the benefit of students within their boundaries. By far, the main reason school districts offer online courses is to provide credit recovery for struggling students (International Association for K-12 Online Learning [iNACOL], 2013; Queen, Lewis, & Coopersmith, 2011). According to the Evergreen Education Group report (Watson, Murin, Vashaw, Gemin, and Rapp, 2012), 62% of school districts use online courses for credit recovery. Further, this report states that “online schools... often are the option of last resort for students who are at-risk, under-credit, or otherwise not successful in a physical school.” Students that are least successful in traditional learning environments are the largest population of students in online learning.

However, while many students have been forced into online learning settings by the need to recover credits from courses they have failed in traditional classrooms, many students have chosen to learn online. Online learning may attract students that prefer solitary learning and are not motivated by social interaction (Harvey, Greer, Basham, & Hu, 2014). Consequently, educators are presented with a challenge to provide effective online learning, rather than replicating methods of the traditional classroom that these students have left by choice or necessity.

## **Struggling Learners**

### **Characteristics of Struggling Learners**

The most common way to identify students in need of educational support is to designate a student as being at-risk. At-risk students are identified by various behavioral, demographic, or medical symptoms that have been found to predict increased likelihood of dropping out of school (e.g., Hill & Brown, 2013; Vesely, 2013). However, in attempts to synthesize the many definitions that label a student at-risk, Worley (2010) finds the label to be used in a loose, inconsistent manner. Further, Worley argues that labeling students as at-risk changes the way principals and teachers treat these students, often causing the pathological behaviors such diagnosis were designed to prevent. Most importantly, however, Worley (2010) points out that regardless of the many criteria for labeling students as at risk of failure in school, there is little to indicate a consistent lack of intellectual ability among this population. Because of the controversial and somewhat ambiguous nature of the at-risk label, it has been determined that subjects in this research will be identified as “struggling learners” to indicate they are students that have been placed in lower tracked courses because of previous course grades or PSSA standardized test scores, regardless of any behavioral or demographic considerations.

## **Academic Tracking**

Academic tracking places students into classes based on various determinants of academic ability. Arguments for the efficacy of academic tracking have focused on the ability of teachers to efficiently meet the needs of a narrow spectrum of learning abilities within a given classroom (Betts & Shkolnik, 2000; Collins & Gans, 2013; Gamoran, Nystrand, Berends, & LePore, 1995; Hoffer, 1992). Critics of academic tracking contend that the influence of classmates on peer outcomes creates disparate learning outcomes between high and low tracked students (Betts & Shkolnik, 2000; Collins & Gans, 2013). Studies that have examined the mean achievement outcomes of academic tracking found that ability grouping has little effect for students compared to peers in heterogeneous groups (Betts & Shkolnik, 2000; Hoffer, 1992; Slavin, 1990). This is in contrast to findings that indicated students in high tracked groups perform significantly better than students in low tracked groups (Betts & Shkolnik, 2000; Hoffer, 1992). More detailed analysis of data revealed that mean scores are comparable between homogenous and heterogeneously grouped schools, but that the distributions of scores within those schools are not equal (Betts & Shkolnik, 2000). Analysis of data from a National Center for Education Statistics survey found that eliminating tracking would improve learning outcomes for students in low academic tracked courses, while causing a concomitant decline in the performance of students in high academic tracked courses (Argys, Rees, & Brewer, 1996).

The causes of disparate learning outcomes require explanation. Examination of data from the Longitudinal Survey of American Youth (Betts & Shkolnik, 2000) has found that tracking does not result in differential resource allocation. Proponents of tracking claim that ability grouping would allow teachers to efficiently focus efforts on the specific learning needs of students, however, this is not reflected in class size, teacher education, or teacher experience



at any ability level (Betts & Shkolnik, 2000; Hoffer 1992). Since allocation of school resources does not account for differences in learning outcomes, other factors must be considered. Gamoran et al. (1995) argue that academic tracking inadvertently segregates students by nonacademic categories as well (e.g., race and income). Hoffer (1992) claims that academic tracking may be viewed as representative of innate ability, causing students in low tracked classes to become demotivated. This contention is supported by research conducted by Carbonaro (2005) who found that effort for 10<sup>th</sup> grade high school students positively correlated with level of ability group across four academic subjects (English, math, science, and history). A study by Gamoran et al. (1995) reported that 8<sup>th</sup> and 9<sup>th</sup> grade students placed in ability grouped classes for English courses had significant variations in student participation and discussion. Students in higher tracked academic courses participated in more class activities and engaged in more class discussion of course content. The researchers claim that an increased level of engagement can improve learning outcomes. Consequently, the effects of peer interactions and student motivation are likely significant when explaining differential learning outcomes in academic tracking. Further, resource allocation does not affect learning outcomes for learners in different academic ability tracked classes.

### **Needs of Struggling Learners**

While it is necessary to be cautious when generalizing about the characteristics of all struggling learners, it is possible to recognize some common characteristics. Learners differ in their levels of perseverance, readiness to avail themselves of learning opportunities, and aptitude for particular content matter (Zimmerman & DiBenedetto, 2008). These common characteristics can be organized into two broader descriptive sets of characteristics identified as self-regulated learning (SRL) and motivation, both of which are discussed below.

## **Self-Regulated Learning and Motivation**

### **Self-Regulated Learning**

Self-regulation describes a set of metacognitive skills that allow a learner successfully complete learning activities. Successful learners possess a range of strategies to regulate their own learning; struggling learners often lack these strategies (Hodges, & Kim, 2010; Jakubowski & Dembo, 2004). Kitsantas and Zimmerman (2009) defined self-regulation of learning as the degree that students are metacognitively, motivationally, behaviorally, and actively responsible for their learning processes. Dembo and Eaton (2000) enumerated the dimensions of self-regulated learning as the ability to manipulate both internal and external qualities, such as motivation, the management of time and strategies, and the ability to optimize physical and social environments for learning. Keller (2008) has modified the ARCS model to incorporate self-regulation as an important facet of learner motivation. Pata (2009) used the term “self-direction” to encompass awareness of learning needs and resources, the selection and use of appropriate learning strategies, and the ability to fairly evaluate learning outcomes. Bednall & Kehoe (2011) identified a wide range of self-regulation strategies in high achieving students. These self-regulation strategies are categorized as learning strategies, depth of process strategies, planning strategies, and cognitive feedback strategies. Learning strategies include goal setting, organization, and self-reward. Depth of processing strategies involve predicting, summarizing, and making inferences. Planning strategies include analyzing a task and selecting appropriate strategies to complete that task. Cognitive feedback strategies are monitoring comprehension and progress, awareness of motivation, and observation of external cues that help goal completion. These skills can define a successful, independent learner, and can be developed through design, instruction, and modeling (Rakes & Dunn, 2010).

## **Online Practices that Support SRL**

It has been found that many differences in performance outcomes for students in online environments can be attributed to variations in motivation and self-regulation (Giesbers et al., 2014). Comparisons between online and traditional classroom environments continually show no significant difference in learning outcomes (Allen et al., 2004; Bediako Asare, 2014; Beebe et al., 2010; Bernard et al., 2004; Cavanaugh et al., 2009; Pentina & Neeley, 2007; Stack, 2015; Summers et al., 2005), however, Levy (2007) has shown that online classes have higher dropout rates than comparable traditional classes. Further, Rakes and Dunn (2010) argue that procrastination is a more serious problem in online settings. Findings that report no significant difference in learning outcomes do not account for challenges unique to online learning environments. Components of self-regulation such as motivation (Archambault et al., 2010), satisfaction (Levy, 2007), and self-efficacy (Astleitner and Hufnagl, 2003; Hodges and Kim, 2010) have been found to positively correlate with course completion rates and successful learning outcomes. As such, research has sought to identify methods to support self-regulated learning in online settings.

Zimmerman and Tsikalas (2005) argue that self-regulated learning is a three-part iterative process of planning, implementation, and reflection. In a meta-analysis of online learning environments, Zimmerman and Tsikalas (2005) found that courses supporting all three steps of this process produce the most successful learning outcomes. A survey of sixteen cyber schools conducted by Archambault et al. (2010) found that more than half employ curricula designed specifically to support self-motivation, self-assessment, time management, and independence. Other research has focused on specific aspects of self-regulated learning.

Dembo and Eaton (2000) proposed using teaching strategies that specifically draw a learner's attention to self-observation and evaluation as a first step to developing independence. The benefits of reflective journals as a means of developing self-regulation with high school chemistry students in a face-to-face setting has been supported by research conducted by Al-Rawahi and Al-Balushi (2015). The researchers compared self-regulation measures using a modified Motivated Strategies for Learning Questionnaire (MSLQ) between students using reflective journals to a control group. Students in the treatment group demonstrated significantly better self-regulation scores than peers in the control group.

Chang (2005) explored the effects of reflective journals and study time records on motivational perceptions in web-based instruction. She found that the 28 students in a one-semester web-based course demonstrated improved measures of responsibility, confidence, and value of learning material as measured by a pre and post-test comparison of MSLQ scores. In subsequent research, Chang (2007) created a web-based self-monitoring form that allowed students in an online foreign language course to record their study times, and learning processes, while reflectively evaluating their daily accomplishments. In this treatment-control study students using the self-monitoring form demonstrated significantly better academic performances and motivational beliefs than their peers in the control group.

Hodges and Kim (2010) compared outcomes between 103 college students enrolled in an online course. One third of the participants received emails with suggestions for explicit self-regulation strategies; one third received personalized (eg. addressed to the student by name) emails with the same suggestions, with the third group served as the control, receiving no direct support for self-regulation. The researchers found no significant difference in learning outcomes between these groups. Nor was there any significant difference in the development of self-

regulation strategies as measured by a comparison of pretest and posttest on the MSLQ. While the effort to directly support self-regulation was consistent with other research, it is possible that the means of support, in this case email, was responsible for the lack of effect. There is no guarantee that a sent email is read in a meaningful way.

A common theme arises when considering the success of methods used to promote self-regulation in online learning environments. Namely, that support for self-regulation should require learners to be actively engaged in the process. Passive support, such as sending email with suggested strategies, has not been shown to be as effective as creating structured opportunities for learners to plan, monitor, and reflect on their learning. These strategies have been shown to promote the metacognitive and behavioral aspects of self-regulated learning. The following section will explore the motivational component of self-regulation.

### **The Role of Motivation in Online Learning**

Motivation to learn stands out as a key feature of self-regulation. Struggling learners perceive that success or failure results from external conditions rather than intrinsic qualities, and consequently, they experience motivation primarily as extrinsic (Matuga, 2009). It has been established that when students perceive motivation as primarily extrinsic it negatively affects their ability to learn (Giesbers et al., 2014; Matuga, 2009; Rakes & Dunn, 2010). In contrast to their intrinsically motivated peers, extrinsically motivated students are less cognitively engaged in the classroom and experience decreased learning outcomes (Yen, Tuan, & Liao, 2011).

There is no reason to believe extrinsically motivated students are less capable of the cognitive and intellectual tasks of school as their intrinsically motivated peers (Zimmerman & DiBenedetto, 2008). However, it is necessary to provide consistent motivational support for struggling learners. Learning environments can be intentionally designed to support motivation

and other self-regulatory skills in struggling learners (Kim, 2012; Pata, 2009; Rakes & Dunn, 2010). Learning environments with support for student autonomy have been shown to benefit student engagement (Giesbers et al., 2014).

Studies have found that student motivation may change in the course of different activities or different domains of knowledge (Angelo, 1993; Keller, 1999). It is possible that students that struggle in face-to-face learning environments may be able to have academic success online. However, it has been found that students that fail academically may lack motivation in general, as well as in domain specific tasks (De Castella, Byrne, & Covington, 2013). Students' failure may be due to their perceptions of the content being studied or aspects of the particular learning environment, such as instructional strategies or social interactions with the teacher or fellow students (Hill & Brown, 2013).

### **Online Practices that Support Motivation According to the ARCS Model**

According to Hill and Brown (2013) motivating instruction focuses on specific, proximal goals that a learner believes are both important and within their power to achieve. Street et al. (2012) identified three design principles they claim serve motivation. Those principles are to make information perceptible, create a welcoming environment, and to promote interaction among students.

These principles of motivational instruction support use of the ARCS model (Keller, 1999). The ARCS model has been proposed as an effective means of designing online instruction to address these challenges (Gormley et al., 2012; Green, 2012; Keller, 1999; Keller, 2009; Keller & Suzuki, 2004). The ARCS model begins with *attention*; creating a welcoming environment that promotes interaction among students serves to attract and hold learners attention and develop a feeling of satisfaction. This will be accomplished by providing

affordances for communication in the form of synchronous and asynchronous messaging. Messaging peers should be an option available at all times, and also embedded within learning activities. Important, relevant goals that a learner is confident they can achieve may serve as a solid foundation for designing online instruction for struggling students; this is consistent with the *relevance* criteria of the ARCS model. Content should relate to students' experiences and lives, as in building curricula around content such as health issues facing young adults (e.g., vaccinations) or environmental issues upon which students can exert influence (e.g., decisions about transportation for new drivers). Perceptible information seems to address the needs of learners to have content presented at an appropriate level for their cognitive skills, allowing them to feel *confidence* according to the ARCS model. Use of formative assessments can ensure that students are progressing through course content at expected rates. Students gain confidence as the instructor reassures that their progress is appropriate and meaningful. Students will then feel *satisfaction* in achieving their goals, as made possible by the previous elements of motivational design.

Studies have been conducted to evaluate the effectiveness of the ARCS design model in online learning environments. Nakajima, Nakano, Ohmori, and Suzuki (2011) used a modified ARCS model to create an online faculty development program to encourage professors to use the ARCS model in developing their own online courses. The eight faculty members surveyed reported positively about their learning experiences and improvements to their own online instruction. However, it can be speculated that university faculty are capable self-directed learners who maintain effective motivational strategies. Further exploration of the role of the ARCS model in designing instruction for learners who are likely to have well-developed motivational strategies reveals similar results.

Pittenger, and Doering (2010) compared the motivational design of four online graduate-level pharmacy courses according to the ARCS model and compared the level of motivational design to completion and performance. The authors found that the 218 self-selected survey participants did not vary enough in final grade to evaluate the relationship between motivational design and performance because all of the subjects earned grades of A's and B's. The authors did, however, suggest that motivational design positively influenced course completion. The author's make this claim based on a 95% completion rate for the course, but give minimal attention to the likely high value graduate students place on course completion, regardless of motivational course design.

Astleitner and Linter (2003) examined the effects of the ARCS model on high achieving students. The authors found that a motivationally enhanced treatment for learners in a 12-week online course produced long-term benefits to all learners, even when highly self-regulated learners saw initial declines in motivational scores. It is curious that students with high levels of self-regulation would initially be de-motivated by motivational enhancement, suggesting that learners with pre-existing strategies for maintaining motivation may struggle to incorporate new strategies into their thinking. In contrast, Astleitner and Hufnagl (2003) found that online instruction designed with the ARCS model was particularly effective at improving motivation and academic achievement with students that demonstrated low confidence in academic settings. Perhaps these students lacked confidence because of a lack of motivational strategies, such as self-regulatory skills.

Distance learning, and especially online learning, is often a challenge for students that are unable to maintain motivation independently. Rates of course completion for online courses are traditionally lower than in face-to-face courses (Chyung, Winiecki, & Fenner, 1998). Chyung et



al. (1998) found that fully online graduate level courses designed according to the ARCS model reduced the drop out rate in a distance-learning program from 44% to 22%. Given the broad range of student ability encountered in this study, it can be speculated that at least some of the students that may have otherwise dropped out were supported in a manner that allowed them to stay enrolled until the course completed.

Some researchers have focused on individual aspects of the ARCS model. Chang and Lehman (2001) focused their efforts on the *relevance* aspect of the ARCS model in a fully online undergraduate English language course and found that students with increased perceptions of relevance also had increased scores on comprehension tests, relative to their peers with lower relevance scores. ChanLin (2009) focused attention on the *confidence* aspect of motivation finding a combination of self-direction, guided self-reflection, and explicit encouragement were necessary to counteract the lack of confidence felt by undergraduate students using a fully online instructional design unit for the first time. Novel learning experiences, such as using Web-based technologies for the first time including course management software, or discussion boards, seem to stimulate attention while increasing anxiety about the likelihood of success.

Huett, Kalinowski, Moller, and Huett (2008) also focused their attention on the *confidence* aspect of the ARCS model by delivering confidence enhancing emails to undergraduate students in a five and one-half week study of a fully online course. It was hypothesized that periodic support of student learning would result in improve confidence. While this study did not find a significant difference in confidence between control and treatment groups, the treatment group demonstrated a significant improvement on post-test scores compared to the control group. The authors speculated that the email messages might have

inadvertently supported other aspects of motivation as identified by the ARCS model such as *attention, relevance, and satisfaction*.

Wyss, Lee, Domina, and MacGillivray (2014) also found confidence to be the weakest aspect of the ARCS model for undergraduate students engaged in blended online learning. The authors evaluated the design of an online instruction unit about cotton used with 58 pre-service teachers. All four aspects of the ARCS model tested positively according to evaluations of student perceptions, with *satisfaction* scoring highest, and *confidence* scoring lowest. It is worth noting that, according to the research, the ARCS model is most effective at promoting *attention, relevance, and learner satisfaction*, while it is possibly less able to effectively develop *confidence*. Consequently, instruction designed in the future according to the ARCS model should devote special attention to the development of learner confidence.

### **Science Education Reform**

Science education reform is a large-scale movement to identify the key components of quality science education and promote and support those components in schools. While interest in science education reform is arguably as old as science education itself, and international in scope (Avraamidou, 2014), this literature review will focus on the themes of science education reform in the United States over the last 35 years. A series of government-based reports on science education reform have been issued in the United States since 1980, all of which contain common themes (Burton & Frazier, 2012).

The initial conversation about science education reform in its modern context began with *Project Synthesis: Final Report* to the NSF (Harms, & Kahl, 1980) and *A Nation at Risk* (National Commission on Excellence in Education, 1983). These reports updated the national perspective on science education since the days of Sputnik and the space race and alerted the

public to the new visions of science education. While these reports relied heavily on promoting fear of global competition (Burton & Frazier, 2012), they had a lasting effect on science education reform in the United States, as seen by the themes of promoting inquiry, professional development, and technology that are common through subsequent reform documents.

The next phase of science education reform built on the impetus of initial reports to promote the development of standards for science education across the country. *Science for All Americans* (American Association for the Advancement of Science, 1990); *National Science Education Standards* (National Research Council, 1996); and *Every Child a Scientist* (National Research Council, 1998) sought to identify specific content and skills requisite for developing a scientifically literate citizenry. Additionally, these reform documents began a conversation about the role of science for individuals and communities that continues in future reform documents.

Across the beginning of the 21<sup>st</sup> Century, a series of science education reform documents repeated the alarm sounded in the 1980s. *Before Its Too Late: A Report to the Nation* (National Commission on Mathematics and Science Teaching for the 21st Century, 2000); *America's Lab Report: Investigations in High School Science* (National Research Council, 2005a); and *Rising Above the Gathering Storm* (Committee on Prospering in the Global Economy of the 21st Century, 2007) brought the fear of global competition once again to the front of science education reform. After two decades of modern science education reform, these documents all concurred that, as a nation, we had not made adequate progress at improving the caliber of science education. Too much science instruction was focused on acquisition of facts and not enough on inquiry, discovery, or scientific skills.

Acknowledging the localized nature of education in the United States, *Systems for State*

*Science Assessment* (National Research Council, 2005b) sought to disseminate science standards for the 21<sup>st</sup> Century in a manner that allowed states to tailor science education reform to their own practices while meeting requirements tied to federal funding.

The most recent science education reform document produced at the national level is the *Framework for K–12 Science Education* (National Research Council, 2012). The *Framework* distills and repeats the common themes of science education reform from the past 35 years. At the forefront is the call for using scientific practices, such as inquiry, to teach scientific reasoning and to acquire science content knowledge. Learning through inquiry is promoted as the best method for students to develop an appreciation for the wonder of science and the ability to think critically about scientific claims. Both of these outcomes further support the development of lifelong science learners who are capable of participating in public discourse about science and scientific decision-making.

Burton and Frazier (2012) conducted an analysis of ten well-known government-based reports on science education reform and identified several themes common to most or all of these reports. The themes of promoting science inquiry and the use of technology are nearly ubiquitous as goals for student learning. Many of these reports also acknowledge the need to properly train pre-service teachers in science content knowledge and skills while supporting the professional development of in-service teachers. The researchers then surveyed 23 experienced teachers with national awards of distinction from organizations such as the National Science Foundation, The National Science Teachers of America, and the National Aeronautics and Space Administration. The researchers sought to discover the alignment between common elements of science education reform and the practices of teachers recognized for the excellence of their instruction. Survey respondents agreed about the importance of scientific inquiry and that

student-centered manipulation of data should be at the heart of classroom practice, however, they also agreed that such methods do not occur “enough.” The area of science education reform that survey respondents least agreed with was the promotion of technology as a method of instruction or as a manipulative for student use. In general, these instructors, with an average of 21.6 years teaching experience, viewed technology as an “add-on” to effective classroom practice, rather than an integral component. The overall conclusion of the researchers is that the expert teachers surveyed saw science education reform as operating at a scale beyond their control. Many of these teachers engage in an array of classroom practices that have been identified as exemplary by national organizations that advocate for science education reform, yet those practices are often limited to individual classrooms (Burton & Frazier, 2012).

The research literature that examines the application of science education reform practices has found several barriers to successful implementation. Unlike the expert teachers surveyed by Burton and Frazier (2012), many teachers are hindered by their lack of content and pedagogical knowledge (Avraamidou, 2014). Science education reform must be implemented within the context of varied social, political, and cultural conventions (Brandt, 2012; Johnson, 2013). Goals and attitudes can vary widely between teachers and administrators reveals, even in nominally pro-reform settings, (Brandt, 2012). Johnson (2013) further demonstrated the interplay of external variables, such as budget constraints, that impede the success of science education reform to the extent that, in 35 years, no state has achieved systemic science education reform.

The goals of science education reform seem to be clear and consistent: promote scientific literacy through inquiry-based instruction that is supported at pre-service and in-service levels. The complexity of large-scale implementation of these reforms appears daunting. But, it is

beyond the scope of this literature review to provide solutions for large-scale problems. It is hoped that providing a context for the nature and recent history of science education reform may successfully position this research within recent science education reforms.

### **Next Generation Science Standards**

The *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) are part of a curriculum reform effort designed to provide an internationally benchmarked science education for all students based on the *Framework for K–12 Science Education* (NRC, 2012). The NGSS integrate discipline specific core content, scientific practices, and crosscutting concepts. Core content are essential ideas from scientific disciplines that students should know as a result of instruction. Scientific practices model methods scientists use to collect information and understand the natural world. Crosscutting concepts span multiple scientific disciplines and connect disparate fields to form a unified body of knowledge. The NGSS provides performance expectations to guide assessment. Performance expectations state what students should be able to do following instruction (NGSS Lead States, 2013; Quattrone, 2013). The implementation of NGSS will require substantial changes in curriculum development and teaching practices. Given the need for new curriculum development and teaching practices, it is necessary to evaluate new methods for achieving these goals. Attention to each of the three facets of the NGSS, with concurrent exemplars, will promote the development of appropriate pedagogical schemes.

**Core content/ evolutionary biology.** The NGSS present standards for core content ideas that are specific to varied scientific disciplines. The NGSS acknowledge that the depth and breadth of scientific knowledge is constantly expanding and daunting in scope (NGSS Lead States, 2013). Consequently, the core content standards do not attempt to cover all possible factual information (NGSS Lead States, 2013). The focus of core content standards is to provide

essential foundational knowledge that will permit learners to add to this base as future, life long learners (NGSS Lead States, 2013).

Biological evolution can serve as an effective exemplar since the depth and breadth of understanding required to comprehend biological evolution is consistent with the goals of the NGSS. Evolution has been called the central, unifying concept of biological science (Baumgartner & Duncan, 2009; Hermann, 2013; & Zogza, 2009). In fact, Dobzhansky (1973) notably claimed that, “nothing in biology makes sense except in the light of evolution.”

Evolution is widely regarded as a difficult and conceptually complicated subject (Baumgartner & Duncan, 2009; Burton & Dobson, 2009; Van Dijk & Reydon, 2010). A comprehensive understanding of evolution requires competence with concepts from throughout the discipline of biology as well as from other science content areas including chemistry, geology, and paleontology (Hermann, 2013; Kampourakis & Zogza, 2009). Research studies have identified specific aspects of biological evolution that are prone to high school students’ misunderstandings. These include conflating popular and technical uses of the word theory (Isaak, 2005; van Dijk & Reydon, 2009), a belief that evolution claims humans have evolved from modern apes (Dougherty, 2011; Heddy & Sinatra, 2013), thinking that evolution proceeds by random chance (Isaak, 2005; Pobiner, 2012), is goal oriented (Pobiner 2012; van Dijk & Reydon 2009), impossible to observe (Isaak 2005), or necessarily results in increased complexity (Heddy & Sinatra, 2013). Given biological evolution’s essential role in the NGSS and its level of difficulty, it is an appropriate science content area for the development of a new reform-based curriculum.

**Scientific practices/ evidentiary reasoning.** Scientific practices are the various methods used by scientists for the development of investigations, models, and theories that build

understanding of the natural world (NGSS Lead States, 2013). The authors of the NGSS make clear that the term “practices” reflects the integration of scientific skills with discipline specific knowledge that informs the judicious application of those skills (NGSS Lead States, 2013). Further, students are expected to develop their understanding of scientific practices through first hand application (NGSS Lead States, 2013). The study and use of genuine scientific practices is consistent with recommendations made about situated learning by Lave and Wenger (1991).

An example of a scientific practice is evidentiary reasoning (NGSS Lead States, 2013; NRC, 2012). Evidentiary reasoning is the two-part process of collecting and arranging information and using that information to support inferences (Pellegrino, Wilson, Koenig, & Beatty, 2014). Information constitutes evidence if it is drawn from reliable observations of the natural world (Brown, Furtak, Timms, Nagashima, & Wilson, 2010). The ability to recognize and use evidence to draw conclusions is a basic part of scientific literacy (Lee, Liu, & Linn, 2011; NRC, 2012).

However, it appears K-12 students are lacking in these essential skills. Schalk, van der Schee, and Boerman (2013) found that students lack the ability to use and articulate the skills associated with evidentiary reasoning at the high school level. Further, examinations of elementary teacher pedagogy found that activities designed to evaluate evidence are often the least emphasized part of the implemented science curriculum (Biggers, Forbes, & Zangori, 2013). Since students lack not only the skills required to use and evaluate evidence, and do not seem to have many opportunities to develop those skills, it is necessary to create instruction that promotes evidentiary reasoning.

**Crosscutting concepts.** Crosscutting concepts are a set of mental tools that apply across all scientific and engineering disciplines and allow learners to engage with new phenomena in a



scientific manner (NGSS Lead States, 2013). Further, crosscutting concepts help learners understand scientific practices by drawing connections between conceptual understandings and the resulting practice within a scientific discipline. The concepts identified by the NGSS are patterns; cause and effect; scale, proportion, and quantity; systems and systems models; energy and matter; structure and function; and stability and change (NGSS Lead States, 2013).

Crosscutting concepts, while given explicit instructional support, are meant to be integrated within the instruction and assessment of scientific practices and core content knowledge. These seven concepts are consistent with “themes” identified in Science for All Americans (AAAS, 1990) and “unifying principles” found in the National Science Education Standards (NRC, 1996). As such, the crosscutting concepts are nested within efforts at science education reform across the past 35 years.

### **Effective Online Science Instruction**

Online learning environments offer possible tools to benefit science learning. Online simulations can improve understanding and attitudes towards science (Gelbart, Brill, & Yarden, 2009; Lamb, 2014; Lamb & Annetta, 2012; Varma & Linn, 2012). Online discussion groups have been found to contribute to improved science understandings (Linn, Bell, & Hsi, 1998; Russell & Aydeniz, 2013). Multimedia presentations of information result in more varied displays of understanding than text alone (Linn, et al., 1998). Further, online learning environments offer students self-pacing and flexibility (Davis & Snyder, 2012; Saltmarsh & Sutherland-Smith, 2010).

While these online learning tools offer options to benefit science learning, it is important to promote best practices. In a survey of secondary science teachers, Crippen, Archambault, and Kern (2013) found little difference in the type and frequency of lab activities used in online or

face-to-face lab instruction. Further, a study of online collaboration found middle school students in a blended online classroom not only had more scientific misconceptions than their peers in a face-to-face settings, those misconceptions increased through the course of online collaboration when compared to a pretest measurement (Wendt & Rockinson, Szapkiw, 2014). While the potential benefits of online science learning are evident, it remains necessary to ensure online science learning aligns with best practices established by research.

Prior research on effective online instruction has synthesized literature on effective classroom instruction with the unique challenges and affordances of online learning environments (Carnahan & Mensch, 2014; LaPrade, Marks, Gilpatrick, Smith, & Beazley, 2011). The following elements of instruction have been identified as consistent components of effective online instruction: active, student-centered learning (Killian, et al., 2014; LaPrade et al., 2011; McLoughlin, 2002; National Survey of Student Engagement [NSSE], 2010; Rice, 2006), social interaction with peers (Moreillon, 2015; Muilenburg & Berge, 2005; Rice, 2006), consistent positive interaction with instructors (Killian, et al., 2014; LaPrade et al., 2011; Muilenburg & Berge, 2005; Rice, 2006), and prompt feedback (Carnahan & Mensch, 2014; LaPrade et al., 2011; McLoughlin, 2002).

Constructivist learning theories identify active, student-centered learning as a way to engage students and make learning more meaningful (Killian, et al., 2014; Rice, 2006). Online learning environments offer the ability for students to work at their own pace and to address content reflective of their own prior knowledge and learning styles (LaPrade et al., 2011; McLoughlin, 2002). A survey of students engaged in online learning has found that student-centered learning environments promote greater satisfaction with learning (NSSE, 2010). Additional research has found student-centered online learning environments to promote better

academic outcomes and higher retention rates among secondary students than comparable teacher-centered environments (Killian, et al., 2014; LaPrade et al., 2011).

Studies have found benefits from the inclusion of social interaction with peers in online learning environments (Moreillon, 2015; Muilenburg & Berge, 2005). A survey of online learners identified a lack of social interactions as a barrier to effective learning (Muilenburg & Berge, 2005). Students engage in more meaningful analysis of course content with peers than they do individually (Linn et al., 1998). Further, anonymous online discussion boards have been found to promote better collaborative results than comparable face-to-face collaborations (Moreillon, 2015). Social interactions between peers have been found to ameliorate feelings of isolation and disengagement, both of which have been recognized as barriers to effective online learning (Rice, 2006).

Another factor that has been found to ameliorate feelings of isolation and disengagement is interaction with the course instructor (Muilenburg & Berge, 2005; Rice, 2006). Surveys of online learners have identified a lack of meaningful interaction with the instructor as a barrier to effective learning (Muilenburg & Berge, 2005). An actively present instructor can serve as a support and guide for learners in a student-centered environment (Rice, 2006). But those interactions must be meaningful (Killian et al., 2014) and in alignment with goals of instructional design (LaPrade et al., 2011).

One way an instructor's presence can positively impact student performance in online learning environments is by providing prompt feedback of student performance (Carnahan & Mensch, 2014; LaPrade et al., 2011; McLoughlin, 2002). Feedback from an instructor can provide valuable cues for self-monitoring (LaPrade et al., 2011). Feedback on formative assessments allows students to monitor their progress towards learning goals (Carnahan &

Mensch, 2014). Additionally, feedback can come from peers and serve as another method of social interaction (McLoughlin, 2002). When this feedback is provided in a timely manner it improves students' confidence and learning outcomes (Carnahan & Mensch, 2014; LaPrade et al., 2011).

While there are many facets of online instruction that have been studied and analyzed for efficacy, these four elements (student-centered, social interactions with peers, interactions with instructors, and prompt feedback) are found to consistently characterize effective online instruction. It is expected that these four elements should be included in the design and planning of future online instruction.

### **Effective Designs for Online Science Instruction**

Researchers tested design features that promote effective science instruction online. Examination of these design features reveals six common characteristics: *inquiry-based instruction*; *scaffolding*; *methods of communication*; *discussion & reflection*; *visualizations*; and *simulations & modeling*. These characteristics are described below.

*Inquiry-based instruction* has been identified in science education reform efforts as a type of pedagogy that effectively promotes acquisition on content knowledge and discipline-specific practices (Hickey, Kindfteld, Horwitz, & Christie, 1999; Geier et al., 2008; Lynch, Kuipers, Pyke, & Szesze, 2005). Inquiry-based instruction requires learners to identify questions, collect and interpret evidence, form explanations, and communicate findings (Hmelo-Silver et al., 2007; Lee, Linn, Varma, & Liu, 2010). However, the process of learning by inquiry is considerably different from didactic pedagogies (Lee et al., 2010). Inquiry-based learning presents unique challenges for learners such as making sense from disparate findings, managing the process of learning independently, and articulating understandings to peers, teachers, and in reflections

(Reiser, 2004).

One attempt to address these challenges is the creation of the Web-based Inquiry Science Environment (WISE) (Lee et al., 2010; Linn, Clark, & Slotta, 2003; Slotta, 2004). WISE is a large-scale, National Science Foundation supported collaborative effort by classroom teachers, technologists, content experts, pedagogy researchers, and curriculum designers to promote inquiry-based instruction through research-based technology applications (Linn et al., 2003). A browser-based interface allows teachers in traditional classrooms to enhance instruction with a library of inquiry projects (Slotta, 2004). One study of the effectiveness of WISE compared the *knowledge integration* outcomes of students in the classrooms of 27 teachers over a span of two years, students showed significant improvements in delayed, end-of-year tests for concepts encountered in WISE projects when compared to students encountering the same content in didactic classroom settings (Lee et al., 2010).

It is noteworthy that research about the effectiveness of WISE relies on *knowledge integration* outcomes (Lee et al., 2010; Linn et al., 2003; Slotta, 2004). Knowledge Integration is a rigorously defined construct created by researchers associated with WISE (Lee, Liu, & Linn, 2011; Linn et al., 1998; Liu, Lee, Hofstetter, Linn, 2008). Inquiry-based instruction requires learners to integrate new knowledge and skills with prior experiences to construct idiosyncratic understandings. *Knowledge integration* measures the complex nature of understandings built from unique perspectives, rather than simple, rote knowledge.

The multifaceted nature of inquiry-based instruction demands complex thinking and problem solving from learners. Researchers acknowledged that learners need support to achieve these advanced methods of learning (Hmelo-Silver et al., 2007; Lee et al., 2010; Linn et al., 2003; Quintana et al., 2004; Resier, 2004). *Scaffolding* has been explored as the best method to

support learners in developing more sophisticated learning methods (Lee et al., 2010; Linn, Clark, & Slotta, 2003; Quintana et al., 2004; Resier, 2004). Originally, scaffolding referred to support from a teacher or knowledgeable peer, but now also refers to instructional designs that structure learning activities in a supportive manner (Reiser, 2004).

While research on scaffolding has focused on different design aspects, a few common goals of scaffolding are apparent. Quintana et al. (2004) developed the *Scaffolding Design Framework of Scientific Inquiry* based on theory and principled analysis of inquiry-based instruction. Design guidelines promoted by the framework include: providing structure for complex tasks and facilitating articulation during an investigation. The dual tasks of structuring complex tasks and facilitating articulation are consistent with research conducted to identify effective design features for online science instruction.

Structuring complex tasks for learners is a common scaffolding approach (Lee, Linn et al., 2010; Linn et al., 2003; Resier, 2004). WISE uses an inquiry map that is built into the user interface (Linn et al., 2003). The inquiry map has been demonstrated to effectively reveal patterns of investigation that allow students to independently direct their own learning process (Linn et al., 2003). Further, research conducted with WISE has found prompts that appear as pop-ups at set times during investigations are effective at promoting reflection and progress monitoring by learners, allowing learners to understand and shape their own learning process (Lee et al., 2010; Linn et al., 2003).

Resier (2004) examined scaffolding in the software programs *Explanation Constructor* and *Computer-Supported Intentional Learning Environments* (CSILE).

*Explanation Constructor* is an element of the Biology Guided Inquiry Learning Environments (BGuILE) software package. *Explanation Constructor* is a computer-based journal that

structures students' construction of questions, explanations, and evidence throughout an investigation. CSILE elicits articulation of scientific ideas from students, requiring learners to engage with complex ideas, make decisions, and reveal gaps in knowledge. Resier (2004) presented both of these programs as effective tools for structuring tasks and promoting engagement with complex aspects of science learning.

While articulation of understandings is a multifaceted construct, one aspect is the communication of questions and explanations between members of a learning community. It is important for teachers and peers to exchange information throughout investigations (Bandura, 1977; Crawford-Ferre & Wiest, 2012). The *methods of communication* used for these exchanges have been the subject of research to identify optimal methods (Chang, Hurst, & McLean, 2015; Crawford-Ferre & Wiest, 2012). A survey of 213 undergraduate and graduate college students found email to be the preferred method of exchange within an online course (Chang et al., 2015). Other frequently used means of communication are course announcements within learning management systems and discussion forums (Chang et al., 2015).

Despite student preferences, discussion forums have received a large amount of attention from researchers (Crawford-Ferre & Wiest, 2012; Dzubinski, 2014; Linn, 2003; Linn et al., 2003; Maddix, 2012; Quintana et al., 2004; Reiser, 2004; and Vonderwell & Zachariah, 2005). *Discussion & reflection* are integral aspects of designs for effective online science instruction. Two reviews of literature agreed that interactions among participants effectively supported online learning when there is a meaningful, shared discourse among participants that is actively facilitated by the presence of the instructor (Crawford-Ferre & Wiest, 2012; Maddix, 2012). Methods of achieving meaningful discourse have focused on different aspects.

Class discussions are social phenomena that involve integrating potentially diverse

student populations representing wide range of cultures, personalities and opinions. A case study by Dzubinski (2014) affirms the role of the course instructor to establish clear expectations for a supportive climate of safety and recognizes and values differences between students. Interviews with course participants revealed that a climate of safety promoted effective participation in online discussions.

Further, experience with online learning environments and discussion forums play a role in the frequency and quality of student participations. A qualitative study of an online graduate course examined transcripts of discussion forums to find that well-structured discussions, with assigned roles within small groups, helped less experienced online learners gradually develop levels of participation comparable to more experienced learners (Vonderwell & Zachariah, 2005). Small group discussions were supported by a review of the literature, as well (Maddix, 2012).

In fact, small group discussions are a feature of WISE designs (Linn, 2003). The use of discussion with peers, in general, has been found to improve accessibility of complex ideas for learners (Linn, 2003). Further, research with WISE has uncovered two salient design features for discussions. First, students are required to make an initial contribution before seeing other student responses. This method increases the diversity of viewpoints within a discussion. Second, WISE prompts participants to support their contributions within a discussion by referring to evidence or resources encountered during an investigation. This two-pronged approach to designing discussions online has been found to improve the quality of discussions, and consequent learning outcomes (Linn, 2003). An additional design feature used in WISE is “Show and Tell.” Students create and share projects to demonstrate knowledge acquired through an investigation. Peers are able to review projects in open, monitored, discussions (Linn et al.,



2003).

Discussions allow learners to exchange ideas about concepts they have encountered. Research on effective online science instruction also seeks to identify methods that allow learners to gain ideas about concepts. One of the methods described is the use of visualizations (Lee et al., 2010; Linn, 2003; Linn et al., 2003). Two guidelines identified in the Scaffolding Design Framework of Scientific Inquiry are using representations to bridge learners' understandings and to use representations that learners can inspect to reveal properties of data (Quintana et al., 2004). Visualizations are an effective form of representation, as demonstrated by research from the WISE group.

A central component of the *knowledge integration framework*, that drives WISE project development, is to make thinking visible (Linn et al., 2003; Lee et al., 2010). In a review of the research literature, Linn (2003) identified visualizations of complex, or otherwise unobservable phenomena as integral to inquiry learning. Scientists represent concepts and data in a variety of ways as part of typical professional practice. However, the same review of literature posited that interpretation of visualizations involves an expert level of skill, which requires support for novice learners. In this case, scaffolding is once again a method to structure a complex task, such as interpreting visualizations (Lee et al., 2010; Linn, 2003; Linn et al., 2003).

The final common feature of successful design for online science instruction is the use of *simulations & modeling* (Beckham & Watkins, 2012; Linn, 2003; and Quintana et al., 2004). Modeling and simulation of natural phenomena is a recognized component of current scientific practice (Linn, 2003, Wilensky & Reisman, 2006). The Scaffolding Design Framework of Scientific Inquiry suggests that learners should be supported in developing discipline-specific practices, such as the use of models and simulations to understand complex phenomena

(Quintana et al., 2004).

The WISE group referred to the development of simulations and models as skills that involves computer coding (Linn, 2003). Simply viewing or using simulations, or models constructed by others is a form of visualization. But, Beckham and Watkins (2012) studied learner use of the commercially available Digital Media Simulations created by Toolwire as an effective method of supporting a focus on learning objectives, while limiting “wandering” by students in less-structured online learning environments. The Digital Media Simulations studied when used by online business students improved learner engagement and promoted deeper learning, as measured by assessments of student projects.

NetLogo is another online simulation tool that researchers have demonstrated to promote scientific understandings (Tisue & Wilensky, 2004; Wilensky & Reisman, 2006). Users observe and make predictions about complex phenomena by using agent-based models (Tisue & Wilensky, 2004). Agent-based modeling takes advantage of the tendency for novice learners to anthropomorphize abstract concepts (Wilensky & Reisman, 2006). NetLogo simulations allow students to actively engage with phenomena, which is an important facet of inquiry-based learning.

The research demonstrating effective designs for online science instruction takes into account the complexity of science education reform and offers several avenues to support this style of learning. The following theoretical framework seeks to build on existing design paradigms to develop online science instruction focused on two persisting challenges for online instruction; evidentiary reasoning and self-regulation.

## **Promoting Evidentiary Reasoning and Self-regulation Online (PERSON)**

### **Theoretical Framework for Designing PERSON**

PERSON is a design framework based on theory and research-based best practices. PERSON is based primarily on a synthesis of Bandura's (1977) social cognitive theory and Lave and Wenger's (1991) situated learning theory, which has been informed by the ARCS instructional design model (Keller, 1999). Social cognitive theory states that individuals learn within their environment through shared experiences and observations of others (Bandura, 1977). In contrast to purely behavioral perspectives on learning, social cognitive theory assumes that learning is a cognitive process that occurs within specific social settings. Learners observe and emulate models of behavior and are conditioned to refine, continue, or terminate emulative behaviors in a constant process of reciprocal influence.

The process of social learning, as described by Bandura (1977) has four steps. First, a learner must attend to a model of behavior. Second, the learner must retain the model of behavior in their memory. Third, the learner must reproduce the observed behavior. And finally, the observed behavior must be reinforced by environmental or social cues. Models of behavior can take the form of live demonstrations, verbal directions, or mediated representations such as video or audio recordings. Each of these procedural steps, however, is dependent on its predecessor. Consequently, the role of attention to a model behavior demands priority. A learner must perceive a novel behavior as important and desirable within a given context. Situated learning provides further exploration of this learning context.

Similarly to social cognitive theory, situated learning is a theoretical perspective that analyzes learning as an integral part of the sociocultural environment in which it occurs (Lave & Wenger, 2011). Situated learning posits the need to learn in environments where knowledge is

used. Learners develop knowledge within the context of a community of practice, and the more closely the learning environment approximates the practical environment, the greater the degree of learning (Lave & Wenger, 1991).

According to situated learning theory, meaningful social context is essential to learning. The social context of situated learning is more important than individual learners or knowledge itself (Driscoll, 2005). Consequently, meaningful learning occurs best when embedded in realistic contexts (Snowman, McCowan, & Biehler, 2009). The context of learning is described as a community of practice. Communities of practice are the sociocultural group that uses a particular body of knowledge. Lave and Wenger (2011), advocate legitimate peripheral participation within communities of practice. A learner gains expertise in knowledge and cultural norms as they move from a peripheral to a central position within a community.

According to Lave and Wenger (2011), all learning is situated in some context. Learning occurs within a culture; whether that culture is practitioners of a profession or the members of a school. Knowledge cannot be separated from the manner it is learned and develops in a reciprocal process with its use (Brown, Collins, & Duguid, 1989). Consequently, a learner that gains and uses knowledge within a community of professionals will develop competency within that profession and a learner in a school community will gain competency within that school. Advocates of situated learning favor realistic contexts that promote learning in environments that are as similar as possible to those where knowledge will be utilized (Langer, 2009).

The synthesis of social cognitive theory and situated learning theory aligns with the design principles of the ARCS model. In both theories, social interaction provides various motivational supports. One of the challenges for the development of asynchronous online instruction is to provide motivational supports in the absence of direct social interactions found

in traditional classrooms. The ARCS model has been proposed as an effective means of designing online instruction to address this challenge (Gormley et al., 2012; Green, 2012; Keller, 1999; Keller, 2009; Keller & Suzuki, 2004). Each of the four dimensions of the ARCS model is considered in relation to the design of instruction created according to these theories.

Social learning theory and situated learning compliment each other by employing interaction among learners as well as between learners and members of communities of practice in order to promote learning. As learners develop skills and understandings associated with behavioral and content norms within a field they are able to incorporate knowledge within cognitive structures that provide relevance for their learning. In order to develop these cognitive structures, several key elements have been included in the design of the online curriculum. The key elements include: *Foundational Knowledge*; *Simulation Study*; *Analyze and Extend*; *Case Study*; *Social Discourse*; *Scaffolding of Self-regulation*; *Scaffolding Evidentiary Reasoning*; and *Evaluation*. Each key element is aligned with one of the dimensions of the ARCS model (Attention, Relevance, Confidence, and Satisfaction). The direct presentation of content information in the *Foundational Knowledge* (Attention) section is followed by experimentation and exploration in the *Simulation Study* (Relevance). The *Analyze and Extend* (Relevance) component includes scaffolded problem solving and prepares students to encounter authentic science in the *Case Studies* (Relevance). Students exchange ideas with peers throughout the curriculum as a method of promoting *Social Discourse* (Relevance). Learners receive *Scaffolding of Self-Regulation* (Confidence) throughout the unit to develop skills necessary to learn independently. The higher order thinking skills associated with *Evidentiary Reasoning* (Confidence) are scaffolded, practiced, and supported through modeling and practice throughout

the unit. *Evaluation* (Satisfaction) provides formative and summative feedback to learners. Each key element of the online curriculum is described in more detail below.

## **Components of PERSON**

Eight key elements have been developed as components of the PERSON framework. Each component is discussed in detail below.

**Evidentiary Reasoning.** *Evidentiary Reasoning* is a core component of the online curriculum and interacts with each of the other components. Evidentiary reasoning is the two-part process of collecting and arranging information and using that information to support inferences (Pellegrino et al., 2014). Information constitutes evidence if it is drawn from reliable observations of the natural world (Brown et al., 2010). The ability to recognize and use evidence to draw conclusions is a basic part of scientific literacy (Lee et al., 2011). The consistent use of evidentiary reasoning allows this online curriculum to better simulate the practice of professional biologists, in keeping with the prescriptions of situated learning (Lave & Wenger, 1991). Additionally, providing scaffolding helps address learners' motivational need for confidence, as described by the ARCS model (Keller, 1999).

**Foundational Knowledge.** The second component of this online curriculum is *Foundational Knowledge*. Students in an online environment must be introduced to basic information and norms of how knowledge is to be represented that allows them to proceed with learning (Bandura, 1977; Lave & Wenger, 1991). To this end, this online curriculum uses videos that introduce basic concepts, terminology, and models of how information is structured in evolutionary biology. Videos are intended to gain learners attention by introducing new and stimulating ideas to address this motivational need described by the ARCS model (Keller, 1999). Video has been selected as the optimum medium for presenting foundational knowledge

because it has been shown to be as effective as traditional face-to-face lectures or other methods of delivering content in distance settings for providing content knowledge (Geri, 2012; Lents & Cifuentes, 2009). Further, video offers affordances such as the ability to pause and repeat instruction, allows learners to utilize supplemental references while viewing, and permits choice in where and when learners will attend to content (Brecht & Ogilby, 2008; Lents & Cifuentes, 2009). While some argument can be made that utilizing videos requires self-regulation skills that students may not have initially (Lents & Cifuentes, 2009), video may disproportionately benefit learners who have been less successful than their peers in traditional classroom setting (Dupuis, Coutu, & Laneuville, 2013). In addition to providing foundational knowledge, video is also employed in each of the other key elements of the online curriculum for modeling learning activities and for providing overviews of the Web-based interface and embedded tools.

**Simulation Study.** The next component of the online curriculum is *Simulation Study*. One of the notable challenges of teaching science in an online setting is the degree to which learners are able to engage in scientific practices. Often, in traditional classroom settings, scientific practice takes the form of laboratory activities. Online learning, however, may provide opportunities for increased learning resulting from the advantages of virtual activities that include the richness of multimedia content, self-pacing, and the convenience of accessing online resources as needed (Hallyburton & Lunsford, 2013; Killian, et al., 2014). Allowing students to manipulate data in simulations will promote meaningful, relevant relationships with content knowledge, as prescribed in the ARCS model (Keller, 1999).

**Analyze and Extend.** The fourth component of the online curriculum, *Analyze and Extend*, focuses primarily on developing critical thinking skills. There is broad agreement that critical thinking, especially that which evaluates scientific arguments, is critical to successful

scientific study (Llewellyn, 2013; Ramsey & Bathe, 2013). The National Research Council's (2012) framework for K-12 science education identified developing explanations and engaging in argumentation as essential scientific practices. Considering the importance of developing critical thinking skills among learners, the *Analyze and Extend* component of the online curriculum requires students to apply foundational knowledge in combination with experiences from simulations and readings to create and defend scientific positions and to critique the arguments of others. The “analyze” learning tasks provide varying degrees of scaffolding, some of which provide concepts and data directly, while others require students to refer to foundational videos, simulations, or readings. The “extend” learning tasks ask students to transfer conceptual understandings from examples they have encountered to novel scenarios that share some similarities with prior examples. The *Analyze and Extend* learning tasks also compliment previous components of the online curriculum by allowing for scaffolding that directs and focuses student attention to relevant details that may be missed by novice learners. Further, examples and scenarios presented in *Analyze and Extend* learning tasks have been created to make meaningful connections between students in content, aligning with the relevance dimension of the ARCS model (Keller, 1999).

**Case Study.** The *Case Study* element of the curriculum provides real-life scenarios as learning tools. Case studies, which use authentic stories to engage students in problem solving (Herreid et al., 2014; Lynn, 1999), are a valuable medium for developing students' skills with scientific practices. Engagement with authentic stories meets the criteria of relevance proposed by the ARCS model (Keller, 1999). Cases provide an engaging way for learners to use recently acquired knowledge in active, student-centered tasks (Herreid, Schiller, Herreid, & Wright, 2014). Students engage with realistic scenarios, applying the critical thinking practiced in the



*Analyze and Extend* component of the curriculum as learners negotiate with the need to make convincing arguments in spite of limited information (Lynn, 1999). Working with limited information and open-ended problems found in case studies allow students involved in the online curriculum to develop scientific understandings from basic concepts to complex, realistic scientific practices.

**Social Discourse.** Throughout the online curriculum is a component of *Social Discourse*. Students frequently engage in discussion with peers and with the course instructor. Bandura (2001) asserts the importance of constructing understanding through activities and interactions with other people, and Lave and Wenger (1991) further supported this assertion by arguing for learning to exist as a result of participation in community knowledge building. In a Web-based environment, students are not limited to learning in isolation, they learn as a community using a Web-based forum. Previous studies have reported that membership in a social group is a predictor of improved learning in online settings and social interaction correlated with student satisfaction and improved motivation (Croxtton, 2014). Further, surveys of undergraduate students and instructors have shown that even communication not directly tied to academic content promotes satisfaction in online settings (Mathieson and Leafman, 2014). Consequently, promoting social discourse with the online curriculum served two purposes: to allow learners to collaborate to build understanding in a community context, and to promote engagement and motivation in what can otherwise be an isolating learning environment as described by the ARCS model (Keller, 1999).

**Support for Self- Regulation.** *Support for Self Regulation* is a further element of this theoretical framework. A first step to developing independence will be using teaching strategies that specifically draw a learner's attention to self-observation and evaluation (Dembo & Eaton,

2000). Creating metacognitive awareness of motivation and learning strategies can create an incentive to develop additional strategies.

Zimmerman and Tsikalas (2005) offer a three step, iterative process for developing self-regulation skills. The steps are forethought, execution, and reflection. Initially, a learner will consider the goal they hope to achieve, and select appropriate strategies for achieving that goal. Next, the learner will carry out their plan. Finally, a learner will reflect on the efficacy of their plan, and consider alternate plans to achieve similar goals in the future. In a meta-analysis of computer-based learning environments, Zimmerman and Tsikalas (2005) found that, while many programs only support two of the three iterative steps required for developing independent learners, those that support all three steps produce positive learning outcomes.

Becoming a skillful, self-regulating learner is a time-consuming process that requires commitment to the development of these skills (Jakubowski & Dembo, 2004). Winne and Stockley (1998) estimated that the development of expert-level skill in self-regulation would require 85% of a student's formal learning time, from kindergarten to 12th grade. Investing such a large proportion of time in any one skill set may not be practical in light of the many demands placed on instruction.

However, Bouchard (2009) considered the increase in online learning programs to demand attention to the development of independent learners. Distance education has one of the highest dropout rates of any learning environment (Bouchard, 2009), largely due to the demands placed on learners to work independently, without any support for the development of requisite skills. Especially in consideration of the low level of self-regulatory skills struggling learners may possess, it becomes necessary to support the development of self-regulatory skills. The

provided support helps students maintain confidence in developing new skills which, according to the ARCS model, will improve student motivation (Keller, 1999).

**Evaluation.** *Evaluation* is the final element of the online curriculum. The science learning objectives described by the NGSS are performance-based, and consequently, difficult to assess with traditional test items designed to only measure content knowledge (Pellegrino et al., 2014). Research conducted by Lee et al. (2011) demonstrated that assessment items requiring explanation demonstrate greater depth of understanding than multiple-choice items. In addition to the demonstration of science content understandings, the NGSS advocates that students also demonstrate evidentiary reasoning skills (Pellegrino et al., 2014). Performance-based assessments can be used for learners to display their evidentiary reasoning skills in addition to content knowledge. They allow students to create explanations that demonstrate their understandings while engaging in tasks that elicit the use of reasoning skills (Liu et al., 2008; Neal 2009; Pellegrino et al., 2014). Performance-based assessments are authentic tasks that allow students to articulate their thinking while working with content knowledge to solve a problem that does not have a single, correct answer (Neal, 2009; Walker, Sampson, Zimmerman, & Grooms, 2011). Providing a meaningful context for displaying student accomplishment serves to create learner satisfaction, as described by the ARCS model (Keller, 1999). The ability to evaluate student knowledge, scientific practices, and demonstrable thinking skills posits performance-based assessments as a suitable tool for measuring the effectiveness of curriculum aligned with the NGSS.

## **Conclusion**

The ongoing growth of online learning at the high school level has outpaced research identifying best practices for that environment. Further, the majority of students in online

learning environments have demonstrated an inability to succeed in traditional classrooms. These struggling learners require specific, focused attention that addresses their needs for self-regulatory and motivational support.

Concurrent with the development of online learning, in general, is the need for high-quality science instruction. Science education reform documents, most recently the NGSS, identify inquiry-based instruction as the most effective means for students to learn scientific content knowledge and practices. Inquiry-based instruction demands that students actively engage with evidence such as observations and data to construct arguments about the natural world.

Given the complexity of thought required to achieve the goals of science education reform, and the challenges associated with online learning environments, especially for struggling learners, it is necessary to consider a multi-faceted approach to learning design. Developing an instructional unit with the PERSON framework is an attempt to address this need. A synthesis of social cognitive theory and situated learning theory promotes peer interactions and modeling in realistic contexts. The ARCS design model provides a foundation for promoting motivation in online learning environments. Finally, scaffolding is used to provide a structure that allows learners to engage in complex tasks such as evidentiary reasoning and self-regulation. This research proposes to test the efficacy of PERSON to promote evidentiary reasoning and self-regulation.

## CHAPTER 3: METHODOLOGY

The purpose of this study was to continue a process to determine the effectiveness of an online curriculum to promote biological evolution understandings, evidentiary reasoning, and self-regulation. The study used a design-based research approach to measure student development following the implementation of the online curriculum (The Design-Based Research Collective, 2003). Pretest measures of content knowledge, evidentiary reasoning, and self-regulation were compared to posttest outcomes. The Biological Evolution Assessment Measurement (BEAM) was used as the primary quantitative data source for content knowledge and evidentiary reasoning. Data about student use of evidentiary reasoning was further supplemented by analysis of student discussion forums. Self-regulation was measured using the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991). Student perceptions of learning experiences were collected with the *Online Instruction Questionnaire*, administered following the posttest. This chapter presents the research questions, setting, research design, instrumentation and data collection.

### Research Questions

This study compared pretest and posttest performance on measurements of three dependent variables as a result of using an online curriculum. The dependent variables were biological evolution understandings, evidentiary reasoning, and self-regulation.

- 1) Whether and to what extent could an online curriculum promote biological evolution understandings with students in high school?
- 2) How well did the online curriculum promote students' evidentiary reasoning?
  - 2a) How well did scaffolding promote students' evidentiary reasoning?
- 3) How did students perceive learning experiences using the online curriculum?

- 4) How well did student baseline self-regulatory ability predict success in using the online curriculum?
- 5) How well did the online curriculum promote student self-regulation?

### **Setting**

The study was conducted in a public school district in eastern Pennsylvania in December 2016. A convenience sample of 83 high school biology students was obtained. The school is located in a suburban area with middle-income households and moderate to low diversity. About one sixth (16%) of the district population participates in the free and reduced lunch program.

### **Participants**

The participants in this study were 83 ninth grade students. The majority of ninth grade students are 14 and 15 years old. The participating high school population has roughly equivalent numbers of male and female students. The ethnic representation of the sample is 92% white students, 3% Hispanics, 3% blacks, and 2% Asians. Two teachers agreed to allow their students to participate in the study. One teacher had one class period of biology with 23 students. The other teacher had three class periods of biology with 19, 21, and 20 students in each class. A one-way ANOVA analysis was conducted to compare both total BEAM pretest scores and pretest scores for BEAM items designed to assess evidentiary reasoning. Neither test revealed significant between class differences on pretest measurements (Total BEAM:  $F=1.712$ ,  $p=.173$ ; evidentiary reasoning items:  $F=1.554$ ,  $p=.208$ ). These four classes of students provided a convenience sample of 83 participants.

## **Research Design**

This study used design-based research to continue to evaluate the effectiveness of the online curriculum design and implementation approach. Findings from the first implementation study (Marsteller & Bodzin, 2015) found that students required support for higher order science process skills, such as evidentiary reasoning, and for metacognitive skills, specifically self-regulation. Based on these findings the PERSON framework was developed to include scaffolding and direct instruction designed to support evidentiary reasoning and self-regulation. Therefore, design-based research is an appropriate methodology for this study since it enables research to focus on iterative design, development, implementation and analysis.

Design-based research promotes consideration of the context in which an instructional intervention occurs (Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003; Tabak, 2004). Pretest and posttest comparisons were used to measure changes in student understanding and skills as a result of curriculum implementation. Analysis of student discussion forums provided additional data about the development of student's evidentiary reasoning skills. A survey given to students following curriculum implementation provided data about potential strengths and weaknesses of the curriculum design. Finally, the researcher recorded qualitative observations that focused on student perceptions of using the curriculum and their self-regulatory abilities.

A design-based research approach was chosen because it provides a holistic view of the complex relationships between theory, instruction, learning environment, and learning outcomes (Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003). Central to design-based research are continuous design revision, gathering information about multiple dependent variables, and capturing social interactions (Barab & Squires, 2004). This study evaluates a

second iteration of this curriculum design and implementation approach. Design-based research acknowledges that elements of learning such as motivation and goal orientation are not stable characteristics of learners but context dependent (Tabak, 2004). Because a learning environment is subject to the active participation of many stakeholders such as students, teachers, and administrators, instructional designs are often implemented with substantial changes from initial design proposals (Collins, Joseph, & Bielaczyc, 2004). Consequently, design-based research may elucidate general theoretical constructs by using context specific implementation as supporting evidence (Barab & Squires, 2004).

Critical views of design-based research focus on the difficulty of generalizing findings and the potential for researcher bias (Anderson & Shattuck, 2012; Kelly, 2004). Curriculum and instructional materials are typically justified with evidence-based research (Clements, 2007). However, curriculum research may take the form of design-based research or randomized trials (Clements, 2007). Randomized trials are generally considered a high standard of evidence-based research due to the ability to attribute causation. Causal relationships, however, are discovered through a process that alters the context of learning by isolating variables and controlling meaningful interactions (Collins, Joseph, & Bielaczyc, 2004; Kelly, 2004). Barab & Squires (2004) warn against sterilizing context in order to improve validity and reliability. Consequently there is need for a means of research that addresses the complex nature of actual learning environments.

Design-based research considers the interactions between the researcher, curriculum, individual learners, and teachers. However, the relationships between the researcher and the participants in design-based research create a potential for bias (Anderson & Shattuck, 2012). The methodology of design-based research addresses the potential for bias by collecting data



from multiple sources such as observations, surveys, tests, and other learning artifacts (DBR Collective, 2003). The multiplicity of data can then be used to triangulate reliable claims supported from multiple perspectives. Validity of claims is achieved through the iterative process as each implementation produces data that either supports previous iterations or gives cause for revision (DBR Collective, 2003). Design-based research is a method of capturing the complex nature of learning and has commensurate means of managing the richness of data it produces to ensure objectivity.

In a review of education research literature published between 2002 and 2011, Anderson and Shattuck (2012) found an increase in the use of design-based research. The value of the design-based research method is generally agreed on as a process that generates meaningful evidence-based claims about complex learning environments that can be used to progressively refine theory and instruction (Anderson & Shattuck, 2012; Barab & Squires, 2004; Collins, Joseph, & Bielaczyc, 2004; Kelly, 2004). This research is a revised iteration of a previously implemented curriculum design (Marsteller & Bodzin, 2015). It is intended that this research contribute to the refinement of the design and implementation of online instruction to promote evidentiary reasoning.

### **Curriculum Description**

A 5-day curriculum unit, made up of 8 different learning task sets has been developed to address topics in biological evolution, consistent with the NGSS core concepts of evolutionary theory (see Table 1). The curriculum was designed using the eight elements of the PERSON instructional framework: *support for self-regulation, evidentiary reasoning, foundational knowledge, simulation study, analyze and extend, case study, social discourse, and evaluation*. The curriculum unit was deployed during five, 90-minute class periods. The online unit was

housed in the management system CourseSite by Blackboard. Learning activities were organized into task set folders that contained access to videos, simulations, questions sets, and forums.

Table 1.

*Description of sequence, content, and core concepts of evolutionary theory*

	Topic/ Description	NGSS Core Concepts of Evolutionary Theory
Task Set 1	<p><b>Foundational Knowledge, The Diversity of Life:</b> Students investigate the source of genetic variation. Students are presented with the concept of diversity within a population. Review of relevant genetics content knowledge to explain traits of individuals and diversity within a population.</p>	<ul style="list-style-type: none"> <li>• Define “biodiversity” and “species.”</li> <li>• Explain adaptation in terms of mutation, fitness, and selection:</li> <li>• The origin and persistence of traits in populations</li> <li>• The role of variation in populations</li> </ul>
Task Set 2	<p><b>Simulation Study, the Struggle for Survival:</b> Students investigate factors that determine which individuals within a population will survive and reproduce. Students are presented with the concept of limited environmental resources (food, shelter, mates, etc.) and the resultant competition.</p>	<ul style="list-style-type: none"> <li>• Explain adaptation in terms of mutation, fitness, and selection:</li> <li>• The origin and persistence of traits in populations</li> <li>• The role of variation in populations</li> <li>• The role of the environment in creating selective pressure</li> </ul>
Task Set 3	<p><b>Case Study, MRSA:</b> Students explore the recent “appearance” of Methicillin-resistant <i>Staphylococcus aureus</i> (MRSA) and how scientists have traced its development and plan for its impact.</p>	<ul style="list-style-type: none"> <li>• Explain adaptation in terms of mutation, fitness, and selection</li> <li>• The origin and persistence of traits in populations</li> <li>• The role of variation in populations</li> <li>• The role of the environment in creating selective pressure</li> <li>• Evolution as a change in proportions of individuals with particular traits within a population</li> <li>• Biological evolution is not a linear, goal-oriented process.</li> </ul>
Task Set 4	<p><b>Simulation Study, Island Biogeography:</b> Students are presented with scenarios involving the migration of a population to an uninhabited island. Based on the characteristics of the island, students predict which members of the population are most likely to survive and reproduce. How does the environment put pressure on a population to</p>	<ul style="list-style-type: none"> <li>• The role of the environment in creating selective pressure</li> </ul>

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Task Set 5	<p><b>Case Study, Lactose (in)tolerance:</b> Students investigate the genetic basis for lactose (in)tolerance and find out how scientists have traced the appearance and persistence of this mutation to specific regions of the world.</p>	<ul style="list-style-type: none"> <li>• Biological evolution is not a linear, goal-oriented process.</li> <li>• Evolution as a change in proportions of individuals with particular traits within a population</li> </ul>
Task Set 6	<p><b>Foundational Knowledge, Charles Darwin:</b> Students explore the work of Charles Darwin, including the voyage of the Beagle, and the years of research leading to the publication of <i>On the Origin of Species</i>. Attention given to Darwin’s methods and the data he collected. Comparisons made between the work of Darwin and Alfred Russell Wallace.</p>	<ul style="list-style-type: none"> <li>• Contrast vernacular definitions of “theory” with biological definitions.</li> <li>• Contrast vernacular definitions of “evolution” with biological definitions.</li> <li>• The role of the environment in creating selective pressure</li> </ul>
Task Set 7	<p><b>Foundational Knowledge, How Evolution Works, Then and Now:</b> Students contrast Darwin’s initial explanations for the mechanism of evolution by natural selection with modern explanations including the incorporation of genetics and punctuated equilibrium.</p>	<ul style="list-style-type: none"> <li>• Biologists may refer to evolution as either a process or the result of the same process.</li> <li>• Differentiate between processes of evolution at genetic, organismal, and population levels.</li> </ul>
Task Set 8	<p><b>Simulation Study, Modifying a Simulation:</b> Students modify a simulation that demonstrates how human activity (e.g. building roads) can impact animal populations (e.g. nesting birds). Students then propose a method of fulfilling human needs while limiting impact on animal populations.</p>	<ul style="list-style-type: none"> <li>• The role of variation in populations</li> <li>• The role of the environment in creating selective pressure</li> </ul>

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*Support for Self-Regulation* was included throughout the online curriculum. Prior implementation of the online curriculum found that students lacked sufficient self-regulatory skills to manage their own learning in an online environment (Marsteller & Bodzin, 2015). Two approaches were used to support self-regulation in this iteration of the online curriculum: self-regulation mini-lessons, and progress monitoring checklists. Self-regulation mini-lessons occurred at the beginning of a task set and included introduction and practice of a specific self-regulatory skill, such as planning, monitoring, control, and reflection. Planning Monitoring and Reflecting sheets were printed and distributed to students as they began each task set (see Appendix E). Each activity within a task set was enumerated, with space for comments, budgeting time, and reflection.

*Evidentiary Reasoning* is a central component of the online curriculum. The current iteration of this online curriculum attempted to address the need for developing evidentiary reasoning skills by increasing practice with fundamental science skills such as interpreting graphs and synthesizing information from multiple sources and providing students with an explicit cognitive model of evidentiary reasoning and prompted reflection. Though designed as a tool for researchers, the Evidence-Based Reasoning Framework (EBRF) was used to develop a model for teaching the structures of evidentiary reasoning (Brown, Furtak, Timms, Nagashima, & Wilson, 2010). Students were provided with a flow chart showing distinct elements that are necessary for successful evidentiary reasoning (see Figure 1). Additionally, student Web-based forums will be used as a medium for reflection on the use of evidence. Students provided with a framework should be able to develop concrete cognitive understanding of the components of evidentiary reasoning (Bandura, 1977). Further, the use of prompted reflection has been shown

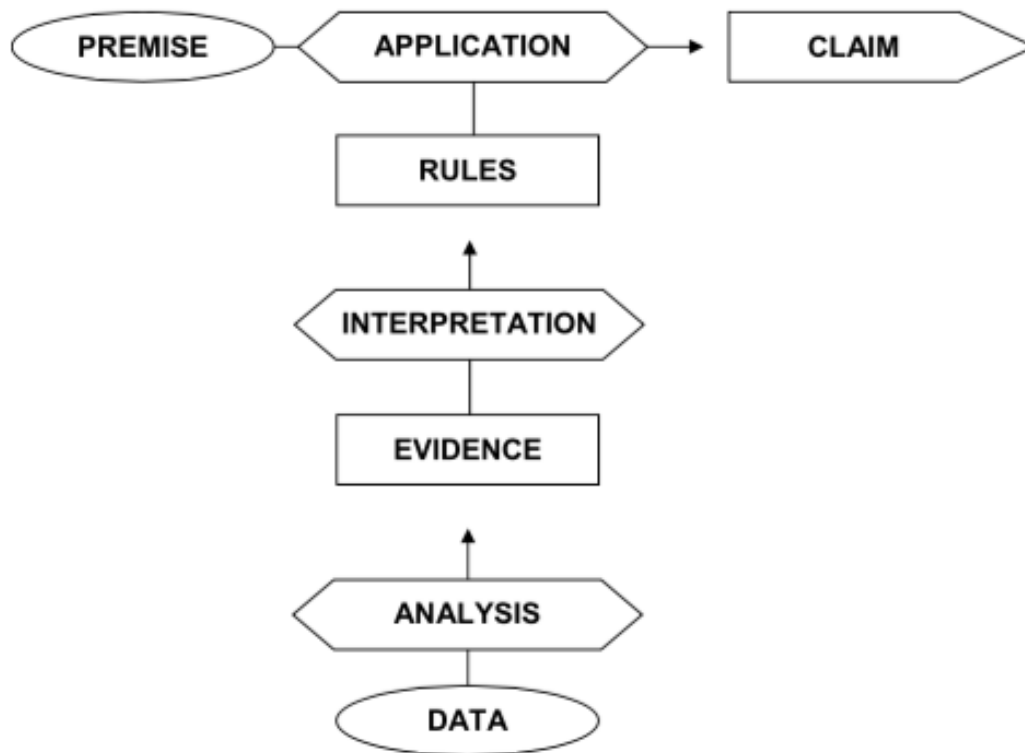
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to increase the use of explanations and generalizations about evidence (Schalk, van der Schee, & Boerman, 2013).

The elements of EBRF include *data*, which refers to all observations of the natural world. *Analysis* refers to the process of synthesizing data to form evidence. *Evidence* refers to statements describing relationships between observations. Evidence is then used in the process of *interpretation* to create rules. *Rules* are statements describing a general relationship that is expected to hold in novel contexts. The process of applying rules to a premise to determine the probability of a claim is *application*. A *premise* is specific circumstances that will result in the outcome described by the claim. The *claim* is a statement about a specific outcome that may be a prediction about the future, an observation about the past, or a conclusion about the present.

Figure 1. EBRF Flowchart

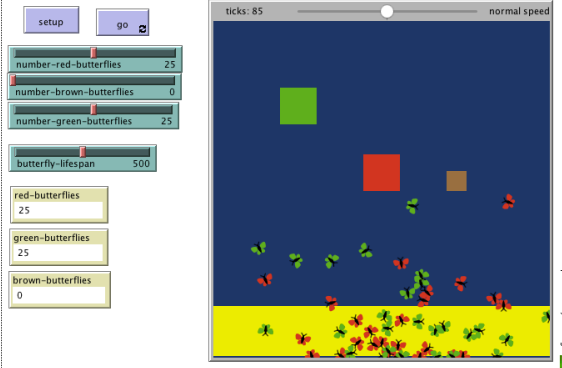


Through the course of the curriculum unit, students received explicit instruction in the EBRF model in the form of a brief video presentation and structured practice in the use of the model as it applies to the unit’s content. A series of guided questions embedded in the *Analyze and Extend* section allowed students to practice use of the EBRF model (see Table 2). As the unit progressed, the degree of scaffolding was gradually decrease until the summative evaluation that asked students to demonstrate their evidentiary reasoning skills without explicit cognitive supports.



Table 2.

*A sample of guided questions to practice use of the EBRF model*

<p>Data: In the Island Biogeography simulation, release 25 red butterflies and 25 green butterflies. Record the number of individuals in each population once the simulation is complete.</p>	<p>This graphic is a screen shot of the simulation to which students are referred in this activity.</p> 
<p>Data: Aside from color, what is the difference between the green and red islands?</p>	
<p>Evidence: Based on your data, what can you determine about the relationship between red and green butterfly populations and the locations of the red and green islands?</p>	
<p>Rules: Make a statement about the relationship between island location and the probability of migration from the mainland.</p>	

Claim: Use the provided map to make a prediction about the comparative likelihood of finding migratory animals from the mainland on each island.



<http://www.aboututila.com/Maps/WPhotos/Bay-Islands-Map.gif>

The *Foundational Knowledge* key element included a daily video that introduced concepts and terminology for the day's activities. Videos utilized a combination of narration, titles, and images to introduce students to the complex vocabulary associated with evolutionary biology. Representing difficult words with a combination of text and narration has been demonstrated to be an effective strategy for vocabulary acquisition (Clark & Mayer, 2003). In addition, Mayer and Moreno (2002) reported that augmenting narration with visual representations of vocabulary reinforces student understanding and retention of new terminology.

In the *Simulation Study*, online simulations were utilized to provide learners with opportunities to develop skills with scientific practices and reasoning. Particularly in regards to the topic of evolutionary biology, simulations manage to bypass the budgetary and time constraints associated with the study of phenomena that occur across substantial, or even vast amounts of time (Latham, 2008). Students were able to interact with otherwise static content to improve their understanding of complex biological processes (Sickel & Friedrichsne, 2012; Wekesa, Kiboss, & Ndirangu, 2006). In addition, Wilensky and Reisman (2006) argued that modern biological science is, in fact, highly mathematical and model-based; therefore the use of models of any sort represents superior affinity with scientific practice. The specific simulation

platform used in the instructional unit was NetLogo, a stand-alone HTML5 application. NetLogo allows users to observe and make predictions about complex phenomena by manipulating agent-based models (Tisue & Wilensky, 2004). Agent-based modeling takes advantage of the common tendency toward personification to make models less abstract and more understandable via relationships with users' personal experiences (Wilensky & Reisman, 2006). Consequently, NetLogo provided support for student understanding of the complex and abstract subject of evolutionary biology. The simulations used for this unit were a combination of existing materials from the NetLogo website (<http://ccl.northwestern.edu/netlogo/>), and simulations developed by the researcher specifically to address the evolutionary biology content presented in the unit.

The *Analyze and Extend* part of the curriculum allowed students to practice scientific skills and formatively assess their developing content knowledge in the form of daily question sets. Materials in the questions sets were classified as quiz and test items, academic prompts for evidentiary reasoning, performance tasks for evidentiary reasoning (Wiggins and McTighe, 2005) and guided questions to practice use of the EBRF model. An example of each of the first three item types is presented in Table 3, an example of guided questions to practice use of the EBRF model can be found in Table 2. The academic prompt for evidentiary reasoning example asked students to bring evidence from their experience with the day's simulation study to support a definition of a stable population. The performance task for the evidentiary reasoning example asked students to utilize data presented in a provided figure to develop an argument about competition at different trophic levels. Students must possess conceptual understanding of trophic levels, the 10% transfer rule, and ecological competition in order to successfully address this question.

Table 3.

*Sample Analyze and Extend items and corresponding question classification.*

Assessment Type	Sample Question
Quiz and Test Items	<p>The process that occurs when the environment is more favorable for one trait than others.</p> <p>A) competition            B) limited resource            C) natural selection            D) artificial selection</p>
Academic Prompts for Evidentiary Reasoning	<p>What does it mean to describe a population as “stable?” How would you recognize a stable population of wolves in the Wolf &amp; Sheep simulation?</p>
Performance Tasks for Evidentiary Reasoning	<p>The figure below illustrates an ecological concept known as the 10% transfer rule. This rule states that only ten percent of the calories consumed in any trophic level are available to be consumed by organisms in the next level. The majority of the calories consumed by an organism are used up in metabolic processes, or lost as heat.</p> <div data-bbox="873 978 1284 1329" data-label="Figure"> <p>The diagram is a pyramid divided into five horizontal sections. From bottom to top, the sections are labeled: Grass (10,000 kcal), Grasshopper (1,000 kcal), Mouse (100 kcal), Snake (10 kcal), and Fox (1 kcal). The title 'Trophic Levels' is positioned to the left of the pyramid.</p> </div> <p>Using the data provided to explain your reasoning, decide whether there is likely more competition among grasshoppers or snakes. Which of these populations would you expect to have more variation? Why?</p>

The *Case Study* elements of the online curriculum allowed students to apply their developing knowledge to real-world problems. Students were directed to Web pages from authoritative sources including Nature, National Institutes of Health, and the University of California Museum of Paleontology. These pages provided evidence focused on particular

examples of evolution, such as MRSA or the spread of the gene for lactose tolerance. The daily question sets associated with these examples asked students to apply evidence from the cases to build arguments that refine their conceptual understanding of biological evolution. For example, students were asked to cite specific evidence from readings to indicate if MRSA infection rates were increasing or declining, and then propose an explanation for the change in infection rates. Finally, students were asked to explain how to determine if the explanation they proposed is accurate.

To promote the *Social Discourse* component throughout the online curriculum, students were provided with one open forum area to post questions at anytime and three required forum areas to communicate with peers and the course instructor. Students were prompted to create and support positions with evidence from course materials. Students were also encouraged to support or challenge each other's assertions with evidence of their own. In some cases, the instructor modeled discourse that promoted effective use of evidentiary reasoning. The three required forum areas included a forum for first impressions about learning online, lactose intolerance and Charles Darwin.

The *Evaluation* section includes using the *BEAM* as a summative assessment. The *BEAM* is described in detail below. Assessment item types are similar in structure and content to those encountered throughout the *Analyze and Extend* section (as seen in Table 3). As such, the assessment was intended to determine to what extent students develop scientific process skills such as developing explanations and engaging in argumentation, and how well students were able to apply cross-cutting concepts such as cause and effect, systems and systems models, and structure and function to the content of biological evolution.

## **Instrumentation and Data Collection**

Eighty participants completed the online curriculum unit. The instruments used for data collection are described below.

### **BEAM**

BEAM was designed to measure biological evolution content understandings and use of evidentiary reasoning. Students completed the BEAM (see Appendix A) before they began the online instructional unit, and completed the same assessment measure when they completed the unit. The BEAM was used in the previous iteration of this design project by Marsteller and Bodzin (2015). The assessment included 15 items: 5 quiz and test items, 4 academic prompts, and 6 performance tasks. A total score of 37 points was possible: 5 points from quiz and test items (1 point each); 10 points from academic prompts; and 22 points from the performance tasks. Both the academic prompts and performance task items were designed to measure evidentiary reasoning, as well as applied content knowledge. Content validity of the BEAM was established by submitting the assessment to college and high school level biology instructors who reviewed items for content accuracy and appropriateness for high school students.

The BEAM was designed to measure curriculum sensitivity (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). That is, the assessment items were aligned to the content and learning activities of the newly developed curriculum. Alignment between curriculum and assessment strengthens interpretation of learning results from the curriculum by increasing the sensitivity of the outcome measures (Lee, Linn, Varma, & Liu, 2010; Lee, Liu, & Linn, 2007). Current recommendations for educational research emphasize the importance of such alignment (Lee et al., 2010; Slavin, 2008).

## MSLQ

The Motivated Strategies for Learning Questionnaire (MSLQ) was designed to assess college student's motivational orientations and learning strategies (Pintrich et al., 1991). This self-report instrument is made up of two sections, one focused on motivation, and the other focused on learning strategies. The motivation section is made up of 31 items about student's goals, values, and beliefs. The learning strategies section has 31 items that identify use of specific learning strategies and 19 items about resource management. The 81 total items of the MSLQ took approximately 20-30 minutes to be administered in class, using a web-based survey platform. Cronbach's alpha was calculated from sample data to provide a measure of reliability.

The MSLQ is made up of fifteen different scales. The motivational scales are: *intrinsic goal orientation*, *extrinsic goal orientation*, *task value*, *control beliefs*, *self-efficacy for learning and performance*, and *test anxiety*. The learning strategies scales are *rehearsal*, *elaboration*, *organization*, *critical thinking*, *metacognitive self-regulation*, *time and study environment*, *effort regulation*, *peer learning*, and *help seeking*. Students rate themselves on a seven-point Likert scale from "not true at all of me" to "very true of me." The mean of items within a scale is used to determine the score for each scale. A high score indicates a respondent possesses the trait associated with each scale.

Reliability statistics reported for the MSLQ are (Pintrich et al., 1991): *intrinsic goal orientation* = 0.74, *extrinsic goal orientation* = 0.62, *task value* = 0.90, *control beliefs* = 0.68, *self-efficacy for learning and performance* = 0.93, *test anxiety* = 0.80, *rehearsal* = 0.69, *elaboration* = 0.76, *organization* = 0.64, *critical thinking* = 0.80, *metacognitive self-regulation* = 0.79, *time and study environment* = 0.76, *effort regulation* = 0.69, *peer learning* = 0.76, and *help seeking* = 0.52.

While the initial design of the MSLQ was intended for use with college students, it was modified for use with high school students on a number of occasions (eg. Al-Rawahi, & Al-Balushi, 2015; Şen, Yilmaz, & Geban, 2015). Modifications included decreasing the number of items to accommodate the attention span of high school students; eliminating scales irrelevant to a high school classroom setting; and reducing the 7-point Likert scale to a 5-point scale. These modification strategies were used in order to develop a version of the MSLQ appropriate for this research (see Appendix B). The number of items was reduced from 81 to 44 by eliminating 7 of the 15 scales that are not of interest to the goals of this research. The motivation scales used include: *intrinsic goal orientation* (4 items), *extrinsic goal orientation* (4 items), *control beliefs* (4 items), and *self-efficacy for learning and performance* (8 items). The learning strategies scales used include: *rehearsal* (4 items), *organization* (4 items), *metacognitive self-regulation* (12 items), and *effort regulation* (4 items). Consistent with other researcher's modifications, the Likert-scale was reduced from 7 points to 5 points. Six questions (items 4, 10, 21, 27, 29, and 39) had words changed to reflect the online delivery of course materials. A final modification was administering the MSLQ as a Web-based survey. Cronbach's alpha was calculated to determine internal reliability of the modified MSLQ. Reliability statistics calculated for the modified MSLQ were: *intrinsic goal orientation* = 0.75, *extrinsic goal orientation* = 0.64, *control beliefs* = 0.72, *self-efficacy for learning and performance* = 0.91, *rehearsal* = 0.76, *organization* = 0.80, *metacognitive self-regulation* = 0.82, *effort regulation* = 0.80.

## **Discussion Forums**

Discussion forum posts were examined for use of evidentiary reasoning. Two discussion forums, Lactose Intolerance and Charles Darwin, prompted students to use evidence in their responses (see Table 4). In addition to explicit prompting, the researcher assumed a participant



role to model evidentiary reasoning and to provide scaffolding for students within the discussion forums. Student posts were classified as either evidence present or evidence absent. Posts with evidence present were further classified to indicate use of evidence to support a scientific assertion, or evidence without a clear connection to a scientific assertion.

Table 4.

*Discussion Forum Prompts*

Lactose Intolerance	The ability to produce lactase, and digest milk as an adult, was subject to pressure from natural selection in human history. Does that same pressure from natural selection exist today? Explain your reasoning and support your conclusion with evidence.
Charles Darwin	Darwin's book is titled <i>On the Origin of the Species</i> . Use what you know about changes within a population to propose how different species may evolve. Refer to simulations and videos from previous days and use evidence that may support your proposal.

**Formative Assessments of Evidentiary Reasoning**

Student responses to guided questions to practice use of the EBRF model were analyzed to determine the efficacy of scaffolding for evidentiary reasoning. Each of the 8 task sets contained *Analyze and Extend* items specifically designed to provide practice of evidentiary reasoning skills and use of the EBRF framework. Student responses for each task set were compared to describe patterns of improvement across the online curriculum unit.

**Online Instruction Questionnaire**

Students completed the *Online Instruction Questionnaire* (see Appendix C) upon completion of the curriculum unit. The questionnaire was designed to collect opinions from students about their learning experience using 14 open-ended items. The questionnaire was

designed to provide further insight into the perceptions and attitudes of the students with regards to learning online.

A grounded theory approach (Strauss & Corbin, 1994) to qualitative research guided analysis of the *Online Instruction Questionnaire*. Line-by-line hand coding was used to evaluate student responses and search for themes. Student responses to the *Online Instruction Questionnaire* in this iteration of the long-term design based research process were analyzed to determine if statements were either positive or negative. Further, open coding analysis sought to uncover emerging themes (Marshall & Rossman, 1989; Patton, 1990) in the students' perceptions.

## CHAPTER 4: DATA ANALYSIS AND FINDINGS

This study investigated if an online instructional unit promoted biological evolution understandings, evidentiary reasoning, and self-regulation. This study is an efficacy study of a second iteration using a design-based research approach to curriculum development. Both quantitative and qualitative data from a total sample of 80 students was analyzed. A total of 83 students were enrolled in cooperating classes, however three students did not provide consent to participate in the study.

Data sources and instruments included (1) the Biological Evolution Assessment Measurement (BEAM); (2) the modified *Motivated Strategies for Learning Questionnaire* (MSLQ); (3) discussion forum posts; (4) formative assessments of evidence based reasoning; (5) *Prediction, Monitoring, and Reflection* forms (PMR); (6) the *Online Instruction Questionnaire*; and (7) field notes. Statistical analysis of the quantitative data was conducted with *IBM SPSS Statistics for Windows Version 24.0* (IBM Corp., 2016). Qualitative coding and analysis were conducted by reviewing data sources for emergent themes in collaboration with a co-rater. All data is presented as it relates to each research question.

### **RQ1: Promoting Biological Evolution Understandings**

The first research question was: Whether and to what extent can an online curriculum promote biological evolution understandings with students in high school? It was hypothesized that students in the sample would significantly increase their understanding of biological evolution content knowledge as measured by a comparison of pretest and posttest BEAM scores. Two trained raters familiar with assessment design and evidentiary reasoning scored the evidentiary reasoning items using a scoring guide. An initial random sample of 10 students' responses was reviewed according to scoring criteria to ensure consistency of scoring. Next, all

student responses were coded independently. Open-ended response items were coded independently for reliability and were found to be in agreement 77% of the time before discussion. Any discrepancies on the scoring guide were resolved via discussions between the coders to achieve 100% scoring agreement.

Although 80 students participated in the curriculum, only 73 completed both the pretest and posttest. Attrition was primarily due to attendance issues. Eleven students missed two or more days of the five-day curriculum implementation, five of these students did not complete the posttest. An additional student was moved to an alternative placement during the curriculum implementation.

A comparison between mean scores on the pretest and posttest is presented in Table 5. The assessment included 15 items: 5 quiz and test items, 4 academic prompts, and 6 performance tasks. A total score of 37 points was possible: 5 points from quiz and test items (1 point each); 10 points from academic prompts; and 22 points from the performance tasks. A paired sample t-test was used to compare student performance on the pretests and posttests. Findings from the t-test indicate that posttest scores were significantly greater than pretest scores ( $p < .001$ ). Effect size was determined by calculating Cohen's  $d$  (Cohen, 1977), which was 0.92. According to Cohen (1977) an effect size larger than 0.80 is considered large. This large effect size demonstrated improved student performance of biological evolution understandings resulting from the online curriculum implementation.

Table 5.

*Comparison of BEAM Pretest and Posttest Scores (n=73)*

Pretest	Posttest	% gain	<i>T</i> -Stat	<i>p</i> -value
<i>M (SD)</i>	<i>M (SD)</i>			
6.58 (2.98)	9.66 (3.74)	46.8	9.766	< .001

**RQ1: Secondary Analysis of the Development of Biological Evolution Understandings**

A subgroup analysis of student performance on the BEAM was conducted. Students' scores were divided into groups based on whether their pretest scores were above or below the average score for those items (see Table 6). The group of student scores that were below average ranged from 0-6 and accounted for 39 of 73 total student scores (53.4%). The group of student scores that were above average ranged from 7-16 and accounted for 34 of 73 total student scores (46.5%). A comparison of gain scores between these two groups revealed that the students with below average pretest scores had greater mean percent gain scores than students with above average pretest scores. However, students with below average pretest scores earned fewer points on the posttest than peers with above average pretest scores. While the average scores for students with below average pretest scores remained below their peers, there was greater improvement, but not to a statistically significant degree. This indicates that students did learn biological evolution content knowledge in the course of the investigation.

Table 6.

*Subgroup Analysis of BEAM gain scores Based on Mean Pretest Scores*

Sub group	Pretest scores <i>M (SD)</i>	Gain scores <i>M (SD)</i>	Mean % gain	<i>F</i>	<i>p</i> -value
Below average	1.78 (1.08)	3.49 (3.05)	80.74		
Above average	6.03 (2.07)	2.62 (2.17)	28.43	1.77	.187

**RQ2: Development of Evidentiary Reasoning**

The second research question asked: How well does the online curriculum promote students' evidentiary reasoning? It was hypothesized that the online curriculum would improve measurements of evidentiary reasoning. Several data sources were utilized to answer this question. First, a subset of the data analyzed for research question 1 was examined. Ten of the fifteen items on the BEAM were specifically designed to assess evidentiary reasoning, 4 academic prompts, and 6 performance tasks. A total score of 32 points was possible: 10 points from academic prompts; and 22 points from the performance tasks. These ten items were reviewed for specific evidence of the development of evidentiary reasoning. Next, two sources of qualitative data were examined to address the sub question: How well does scaffolding promote students' evidentiary reasoning? Student discussion forums and specially designed formative assessment items were reviewed to examine the impact of scaffolding in the development of evidentiary reasoning.

Assessment items on the BEAM assessing evidentiary reasoning were analyzed using a paired sample t-test. A comparison between mean scores on evidentiary reasoning items on the

pretest and posttest are presented in Table 7. Findings from the t-test indicate posttest scores were significantly higher than pretest scores for items associated with evidentiary reasoning ( $p < .001$ ). Cohen's  $d$  (Cohen, 1977) was calculated to determine an effect size of 0.80. This effect size is congruent with Cohen's (1977) definition that effect sizes larger than 0.80 are large. As such, this large effect size demonstrated improved performance on assessment items associated with evidentiary reasoning resulting from the online curriculum implementation.

Table 7.

*Comparison of BEAM Pretest and Posttest Scores for Items Assessing Evidentiary Reasoning (n=73)*

Pretest	Posttest	% gain	<i>T</i> -Stat	<i>p</i> -value
<i>M (SD)</i>	<i>M (SD)</i>			
3.66 (2.58)	5.99 (3.26)	63.66	7.940	< .001

### **RQ2: Secondary Analysis of the Development of Evidentiary Reasoning**

A subgroup analysis of student performance on BEAM items designed to assess evidentiary reasoning was conducted. Students' scores were divided into groups based on whether their pretest scores for evidentiary reasoning items were above or below the average score for those items, as seen in Table 8. The group of student scores that were below average ranged from 0-3 and accounted for 40 of 73 total student scores (54.8%). The group of student scores that were above average ranged from 4-12 and accounted for 33 of 73 total student scores (45.2%). A comparison of gain scores between these two groups reveals that the students with below average pretest scores had a greater mean gain than students with above average pretest scores. However, students with below average pretest scores earned fewer points on the posttest than peers with above average pretest scores. While the average scores for students with below

average pretest scores remained below their peers there is greater improvement, but not to a statistically significant degree. This indicates that students did learn evidentiary reasoning skills in the course of the investigation.

Table 8.

*Subgroup Analysis of Evidentiary Reasoning Items Based on Mean Pretest Scores*

Sub group	Pretest scores <i>M (SD)</i>	Gain scores <i>M (SD)</i>	Mean % gain	<i>F</i>	<i>p</i> -value
Below average	1.78 (1.08)	2.76 (2.57)	155.06		
Above average	6.03 (2.07)	1.78 (2.35)	29.37	.001	.973

### **RQ2a: How Well Does Scaffolding Promote Students' Evidentiary Reasoning?**

Discussion forums were examined to determine if students used evidence when explicitly directed to do so, and further to determine if students used evidence to support scientific arguments. Student use of evidentiary reasoning in discussion forums is summarized in Table 9. The researcher and a co-rater examined the entire sample of 190 discussion forum posts, coding posts according to whether or not students used evidence, and if that evidence was used in support of scientific arguments. Initial agreement between co-raters was found to be 87%. The co-raters met to resolve discrepancies, resulting in 100% agreement for all discourse interpretations. It was found that students used evidence in 38.2% of discussion forums, and that 6.3% of discussion forum posts used evidence support of scientific arguments. An example of evidence used in response to the lactose tolerance forum prompt is: "Today, the ability to digest milk as an adult seems like a clear benefit, but that wasn't always the case. Lactose tolerance is



only advantageous in environments and cultures where humans have access to domesticated dairy animals.” An example of evidence used to support a scientific argument in response to the same prompt is “The pressure from natural selection does not exist as much so as it did in the past. This is because the need for lactase is not as desperate and beneficial to certain populations and humans as it used to be to the extent where natural selection favored those with it. This can be supported by the fact that only 35% of the human population can digest lactose beyond the age of 7-8.” Second, analysis was conducted to understand how students used evidence-based reasoning during daily tasks sets structured to provide scaffolding.

Table 9.

*Student Use of Evidentiary Reasoning in Discussion Forums*

Forum	Total posts	Posts citing evidence	Posts citing evidence that supports scientific assertion
Lactose intolerance	98	38 (38.8%)	10 (10.2%)
Charles Darwin	93	23 (24.7%)	2 (2.2%)

Daily question sets, representing the *Analyze and Extend* part of the curriculum, contained formative assessment of evidentiary reasoning. Each question set contained 2-4 items specifically addressing evidentiary reasoning in a manner consistent with the EBRF model that was distributed to students and supported with instructional video mini-lessons. The level of scaffolding was gradually decreased throughout the curriculum. The initial question set provided guidance through multiple-choice selections for students. The next two question sets

incorporated fill-in the blank items for prompts. The subsequent two question sets were open-ended, but mirrored the structure of previous sets. The final question set was open-ended, but did not ask students to record data or state a rule. The number of students that completed daily task sets ranged from 59-77, as seen in Table 10. Students who did not complete all six daily task sets were assigned scores of zero for any missing sets. Students that were missing three or more daily task sets were dropped from the data set. Attrition was most likely due to attendance issues. The researcher and a co-rater examined 414 responses to daily question sets, coding posts according to whether or not students accurately employed techniques of the EBRF model (see rubric, Appendix D). Initial agreement between co-raters was found to be 82%. The co-raters met to resolve discrepancies, resulting in 100% agreement. It was found that student scores declined from 96.5% in the first set to 40.8% in the last set.

Table 10.

*Student Use of Evidentiary Reasoning Components in Formative Assessments*

Set	<i>n</i>	Data		Rule	Claim		%
		Mean ( <i>SD</i> )	Evidence Mean ( <i>SD</i> )	Mean ( <i>SD</i> )	Mean ( <i>SD</i> )	Total Mean ( <i>SD</i> )	Mean score
2	77	1.95(.22)	1.99(.11)	2.00(.00)	1.78(.42)	7.72(0.46)	96.5
3	70	1.70(.67)	1.43(.75)	0.97(.72)	0.86(.55)	4.96(2.07)	62.0
4	70	1.49(.56)	1.31(.71)	0.99(.77)	1.26(.81)	5.05(2.37)	63.1
5	71	1.33(.79)	0.77(.85)	0.53(.71)	0.83(.86)	3.46(2.33)	43.3
6	59	1.19(.86)	0.81(.78)	n/a	0.68(.78)	2.68(1.84)	44.7
7	67	n/a	0.66(.73)	n/a	0.97(.78)	1.63(1.15)	40.8

*Note.* Each evidentiary reasoning component was scored from 0-2; sets 2-5 had 8 total possible

points, set 6 had 6 total possible points, and set 7 had 4 total possible points.

A linear correlation analysis was conducted to determine if student performance on items in daily question sets designed to formatively assess scaffolded evidentiary reasoning predicted outcomes in the gain scores for BEAM items assessing evidentiary reasoning. Of the 80 students that participated in the curriculum implementation only 66 completed the daily task sets, as well as both the pretest and posttest. Findings from the linear correlation indicate that total scores on formative assessments of evidentiary reasoning did not significantly predict the standard deviation of the BEAM posttest items designed to assess evidentiary reasoning (adjusted  $R^2 = 0.016$ , standard error of the estimate 2.497). ANOVA analysis conducted with the same variables indicate that BEAM gain scores were not strongly predicted by performance on daily evidentiary reasoning tasks predicts ( $F=0.007$ ,  $p=.933$ ). Students that successfully completed the Analyze and Extend items designed to promote evidentiary reasoning did not perform significantly better on items on the BEAM that assessed evidentiary reasoning compared to their peers.

### **RQ3: Student Perceptions of the Online Learning Experience**

The third research question asked: How do students perceive learning experiences using the online curriculum? Responses to the *Online Instructional Questionnaire* were analyzed for themes that emerged across responses to related questions. Of the 80 students who participated in the curriculum only 67 (83.8% of participants) responded to the 14 items in the *Online Instructional Questionnaire* (See Appendix C), responses to 35 items were left blank, providing a total of 903 responses. In order to determine emergent themes, questionnaire items were grouped according to four categories: general items about online learning (questions 1-3), items about using discussion forums (questions 6-9, and question 13), items about evidentiary

reasoning (questions 10-13), and items about using online learning environments in the future (questions 2-3). Question 13 appears in two categories because it addresses both the use of discussion forums and evidentiary reasoning. Additionally, question 14 was an open response asking students for any additional information they wished to share. Responses to this item were coded and grouped with prior categories as appropriate. Qualitative data analysis focused on particular perceptions and/or experiences that the researcher viewed as relevant to the research question (Maxwell, 2005). An initial examination of general attitudes towards online learning will serve as an introduction to student perceptions, with more specific detail to follow.

While students were asked to compare learning online with their prior classroom experiences and to identify positive and negative aspects of their experiences, most students responded to these survey items by expressing qualitative comparisons. Though students were not asked explicitly for a preference, a majority of students expressed a preference for either traditional or online learning; 26 (38.8%) students stated a preference for traditional learning environments and 24 (35.8%) students stated a preference for online learning environments.

A preference for traditional learning environments was frequently stated in survey response items. Statements such as “I do not really like web learning,” “learning online is not for me. So I had trouble with it,” and “I do not learn very well online” were typical responses. Students identified learning online as “hard” or “boring” when referring to specific tasks such as forum discussions or question sets, and when making general statements about learning online. One student wrote, “It was a new way for me to learn and in the past I wanted to try [online learning] and I realize that it is harder than I thought.” Another wrote “It was much harder because I had to teach myself and I still don’t understand. I [would] rather have a teacher teach it to me.” Another student concurred, stating, “I don’t like [online learning] because it was really

difficult. Some students can't learn from computers and I can't. I don't understand what I am doing and I'm really confused."

While a number of students were definite in their preference for traditional learning environments, a similar number expressed an opposite opinion. Learning online was also frequently stated as a preference in survey response items. One student described overcoming initial trepidation by learning metacognitive skills in the instructional unit, "At first I really hated [online learning] because I just found the videos super long, but after learning new ways to stay focused I really enjoyed it and I really recommend it." Another student articulated why he preferred learning online, "I got to work at my own pace individually without the stress of feeling compelled to do better than other students, or have to worry about being forced into an environment to socialize with others and put me out of my comfort zone." A third student stated, "I liked [online learning] a lot better, because I love being on electronics, and also I could work at my own pace." Self-pacing was mentioned by 15 (22%) of respondents as one of the most beneficial aspects of learning online.

Students agreed on several beneficial aspects of the online curriculum, in addition to self-pacing, a large number of comments identified the use of videos as the best part of learning online. A student applied metacognitive self-awareness in commenting, "I am a visual learner, so watching videos with different charts and tricks to remember words is an easy way for me to learn." Another student commented, "I could re-watch videos to see if I missed anything and I could work at my own pace. [There was] no teacher that keeps talking." Another agreed, writing, "the best part was watching the videos because I can replay what was said and I can't do that in a real class." There was apparent overlap between the appreciation of using videos as a learning tool and self-pacing.

While some students found aspects of online learning beneficial there were others who had difficulty engaging with the online learning environment. Students frequently complained of technical issues, mostly related to “lagging” and “reloading” content. But the most frequent complaint from students was about course readings. Readings were frequently described as “hard,” “boring,” and “long.” When asked what changes would make entirely online classes more enjoyable three different students wrote, “less reading,” another wrote, “not having too read to much.”

Survey items asking about discussion forums were consistent with other categories in revealing divergent opinions among students. Many students expressed a reluctance to participate in discussion forums with peers or the instructor. One frequent response to questions about using forums to interact with peers or the course instructor was “I didn’t.” Several students further explained that they were reluctant to expose themselves to judgment from their peers. A student commented that the most frustrating part of interacting with peers with the online discussion forum was, “the pressure of having other individuals having access to see what I post.” One other student made a similar comment, “people could see if you were right or wrong.” And while some students stated a reluctance to be exposed to peer judgment, others were frustrated by a lack of seriousness on the part of classmates.

Discussing a lack of seriousness a student stated that peer interactions were “stupid because people would say stuff that has nothing to do with the course.” Another student agreed, writing, “Some students would often get off track or not answer questions.” Consequently, a number of students refused to participate in discussion forums, did so reluctantly, or provided answers that were off topic or, as one student described them, “silly.”

When asked specifically about interacting with the instructor in discussion forums 19

students stated that they did not interact with the instructor, and an additional four claimed there was “nothing” they could describe as best about those interactions. An additional common frustration stated by 6 (9%) students was a perceived delay in feedback from the instructor. However, this should be contrasted with 19 (28%) students that claimed to have “no frustrations” when interacting with the teacher. Students also claimed that asking questions, correcting mistakes of understanding, and receiving detailed, individualized feedback were benefits of interacting with the course instructor in the discussion forums.

Further examination of the survey item (question 13) about the impact of instructor participation in forums on the use of evidence to make an argument revealed that a comparable number of students (18, or 26.8%) either did not use the forums or perceived no impact. Three students stated that the instructor did not respond to their forum posts. Conversely, 14 (20.9%) students claimed that the instructor’s participation in discussion forums improved or helped their understanding of the use of evidence in argumentation. Ten additional students (14.9%) specifically identified instructor feedback and supportive hints as beneficial impacts of interaction with the instructor in discussion forums. One student stated, “We would see what he would have to say and realize what we left out and sometimes we left out a lot of evidence.” Another wrote that the instructor, “made it so if we didn’t understand a question he would talk to us and discuss it with us.”

The development of evidentiary reasoning skills was further examined by the third category of survey items. The category of survey items examining evidentiary reasoning sought to ascertain prior experiences with evidentiary reasoning, the use of course resources to develop and practice evidentiary reasoning, and the impact of the instructor in developing these skills, which was discussed previously. Twenty students (29.9%) misinterpreted the survey item asking

about prior experience with using evidence in support of classwork (question 10) and wrote about their experiences with the online instructional unit. Twenty-eight students (41.8%) stated that they had used evidence in prior classes, or that using evidence was familiar. One student wrote, “Yes, we have had to use data or evidence in our homework and classwork before. I have also used evidence and data to support my opinions before.” Seven students (10.4%) claimed to have no prior experience with using evidence for any classes. Subsequent survey items asked about using evidence within the online curriculum.

Students were asked about using the Evidence Based Reasoning chart that was provided as a handout and supported with video instruction. Eighteen students (26.9%) wrote about their appreciation of a visual resource that articulated a “correct” methodology for using evidence that improved both understanding and confidence. An additional 13 students (19.4%) claimed that the chart offered “some” help, but did not specify how it helped. Eleven students (16.4%) stated that the EBR chart had no impact on their understanding. Three (4.4%) stated that the chart was confusing. One student claimed to have “hated” the chart. One other student claimed to not have used the chart. A third student did not remember the chart.

In question 12 of the *Online Instructional Questionnaire*, students were asked to describe the impact of daily practice on their understanding of how to use evidence to make an argument. Fourteen students (20.9%) claimed to have not engaged in daily practice of evidentiary reasoning problems. However, an examination of the results from daily practice tasks, presented above in the section on formative assessment of evidence based reasoning, shows that only one question set had fewer than 66 student responses. This indicates a possibility that the students that claimed to not participate in daily practice were not accurate. Potential reasons for this discrepancy will be presented in the discussion section.



In contrast to the students that claimed to have not participated in daily practice activities, 27 students (40.3%) stated that these activities improved their understanding of evidentiary reasoning. One student wrote, “I got to see more examples of when I’d have to use evidence to make an argument.” Several students stated that daily practice improved their ability to gather evidence and evaluate arguments, while two additional students stated that they gained a greater appreciation of the use of evidence. Responses to survey items continue to demonstrate sharply divided opinions between students.

The fourth category of survey items (questions 4 and 5) asked students to imagine future online courses they may encounter and to predict the aspects of those courses that could be most enjoyable or frustrating. Across both of these items 17 responses (25.4%) indicated that students were not interested in taking an online course in the future under any circumstance. When asked to describe what could make an online course more enjoyable, one student wrote, “No way!” Some students indicated a poor sense of self-efficacy in online learning environments. The following student exemplifies the sense of poor self-efficacy, stating that the most frustrating aspect of taking a course online would be “probably the fact that I will do so poorly since I don’t learn well this way.” Nine responses (13.4%) indicated a need for increased social interaction. Eight responses (11.9%) asked for videos to become more engaging. One student wrote, “I would enjoy more exciting videos and colorful videos.” Others cited technical issues, such as losing network connections, while other wrote that learning online involved too much technology.

In addition to critiques specific to online learning, many students felt frustrated by aspects of the course that are independent of learning environment, such as content, the quantity and difficulty of work, repetition of daily tasks, deadlines, and reading. Other students just

wanted to be able to listen to music while they worked, but this was not allowed according to the cooperating teachers' policies. The nature of the survey items assessing student perceptions of learning in online environments in the future did not generate many positive comments. Twelve percent students stated that “nothing” would frustrate them about learning in online environments in the future, or that the instructional design of the online curriculum was “good as is.” One student wrote that, “my mom takes college classes online and I have always loved the way it was set up. Again, the whole work at your own pace and not sit in a class and write on paper is so amazing.”

While some students indicated a positive experience learning in an online environment, there were persistent negative comments from several students about nearly every survey item. Several students responded to multiple prompts with generalized negative comments about lacking participation, effort, and interest. When asked about either positive or frustrating qualities of discussion forums, comments about not enjoying the forums, not benefitting from the forums, or not using the forums were frequent. Interactions with the instructor and peers were described as neither enjoyable nor impactful. These same students summarized their experience with the online instructional unit by stating that online learning was “not for me,” or simply, “never again!” The students that indicate a generalized negative attitude towards online learning represent one aspect of some themes that were detected across all student comments.

In general, many students described aspects of the online instructional unit as either “easy,” “hard,” or “boring.” Many students stated reluctance to use discussion forums, while others indicated frustration using the forums, with one student writing, “You couldn't type everything that you were thinking.” Some students consistently described an aversion to course readings, or readings in general. A few students stated that they would prefer less or no course

work. In sum, these generalized themes suggest an attitude toward school and learning that was of interest to the current research.

#### **RQ4: Self-Regulation as a Predictor of Success**

The fourth research question asked: How well does student baseline self-regulatory ability predict success in using the online curriculum? It was hypothesized that measurements of self-regulatory ability as measured by a modified version of the MSLQ would correlate significantly with success in using the online curriculum as measured by BEAM gain scores. The MSLQ was scored according to instructions in the MSLQ manual (Pintrich, Smith, Garcia, & McKeachie, 1991). Students rated themselves on a five point Likert scale from “not at all true of me” to “very true of me.” Scales were constructed by taking the mean of the items that make up each scale. Scales were summed into corresponding sections of motivation and learning strategies. Chronbach’s alpha was calculated to determine internal reliability of the modified MSLQ. Reliability statistics calculated for the modified MSLQ are: *intrinsic goal orientation* = 0.75, *extrinsic goal orientation* = 0.64, *control beliefs* = 0.72, *self-efficacy for learning and performance* = 0.91, *rehearsal* = 0.76, *organization* = 0.80, *metacognitive self-regulation* = 0.82, *effort regulation* = 0.80. A linear correlation between MSLQ pretest scores and BEAM gain scores is presented in Table 11.

Table 11.

*Linear Correlation Between MSLQ Pretest Sections with BEAM Gain Scores*


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MSLQ	Adjusted $R^2$	Standard error of estimate	$F$ score	$p$ -value
Self-regulation scale	0.010	2.682	1.753	0.190
Motivation section	0.008	2.686	1.582	0.213
Learning Strategies section	0.021	2.669	2.516	0.117
Total	0.022	2.667	2.611	0.111

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Although 83 students participated in the curriculum, three did not consent to participation in the study, 80 completed the MSLQ pre-test, and only 73 students had valid BEAM gain scores. Attrition was primarily due to attendance issues, as discussed previously.

A linear correlation analysis was conducted to determine if student scores on MSLQ predicted outcomes in BEAM gain scores. A linear regression was used to compare student performance on the MSLQ pretests and BEAM gain scores. Findings from the linear regression indicate that MSLQ pretests did not significantly predict BEAM gain scores. Total MSLQ scores had an adjusted  $R^2$  of 2.2%, indicating that 1% of variation in BEAM gain scores may be accounted for by the total MSLQ pretest scores. Analysis of subscales for the MSLQ demonstrated correlations explaining 0.8% of the variance for the motivation subscale, and 2.1% of the variance for the learning strategies subscale. Further analysis of a linear regression between only the self-regulation scale and BEAM gain scores demonstrated a correlation of 1%.

This low degree of correlation indicates that differences in student success in using the online curriculum cannot be predicted by self-regulatory ability as measured by the MSLQ.

### **RQ5: Promoting Self-Regulation**

The fifth research question asked: How well does the online curriculum promote student self-regulation? It was hypothesized that students in the sample would significantly increase their self-regulatory ability as measured by a comparison of pretest and posttest MSLQ scores. The MSLQ was scored according to instructions in the MSLQ manual (Pintrich, Smith, Garcia, & McKeachie, 1991). Scores for both the overall MSLQ and the self-regulation subscales were calculated. A comparison between mean scores on the pretest and posttest is presented in Table 12.

Table 12.

*Comparison of MSLQ Pretest and Posttest Scores (n=66)*

	<i>M</i>	<i>SD</i>	<i>p</i> -value
MSLQ pretest	26.07	4.36	
MSLQ posttest	26.71	3.95	0.154
Self-regulation scale pretest	3.01	0.69	
Self-regulation scale posttest	3.02	0.56	0.934

Although 80 students participated in the curriculum, only 66 completed both the pretest and posttest. Attrition was primarily due to attendance issues. It is also likely that some students did not have enough class time to complete the MSLQ survey after finishing the BEAM.

A paired sample t-test was used to compare student performance on the pretests and posttests. Findings from the t-test indicate that total posttest scores were not significantly

different than total pretest scores ( $p = .154$ ). Effect size was determined by calculating Cohen's  $d$  (Cohen, 1977), which was 0.16. Additionally, findings from the  $t$ -test indicate that posttest scores for the self-regulation subscale were not significantly different than total pretest scores for the self-regulation scale ( $p = .934$ ). Effect size was determined by calculating Cohen's  $d$  (Cohen, 1977), which was 0.02. According to Cohen (1977) an effect size must be at least 0.20 to be considered small. This effect size does not demonstrate improved student self-regulatory ability resulting from the online curriculum implementation.

Additionally, it was hypothesized that student use of progress monitoring forms would act as a scaffold to promote self-regulation. Students were provided with Planning, Monitoring, and Reflection sheets corresponding to each of the 8 task set (see Appendix E). Two trained raters familiar with assessment design and self-regulation scored the PMR sheets using a rubric that assigned scores between 0 and 9 (see Appendix F). All 80 students that participated in this investigation completed a majority of progress monitoring forms. Students were assigned to descriptive categories of "proficient", "developing", or "poor" self-regulatory skills based on mean scores across all forms. An initial random sample of 10 students' responses was reviewed according to scoring criteria to ensure consistency of scoring. A summary of scores for progress monitoring forms is presented in Table 13.

Table 13.

*PMR scores (n=80)*

Category	Score range	<i>n</i> of students
Proficient	7-9	31 (38.75%)
Developing	4.5-6.9	37 (46.25%)
Poor	0-4.4	12 (15.0%)

An examination of the relationship between PMR scores and MSLQ posttest scores is presented in Table 14. A one-way ANOVA compared categorical outcomes of student PMR performance with MSLQ posttest scores for self-regulation, motivation, learning strategies, and total posttest score. None of these comparisons yielded statistically significant relationships. These findings do not demonstrate improved student self-regulatory ability resulting from the use of Planning, Monitoring, and Reflecting sheets.

Table 14.

*Comparison of Categorical Values of PMR Scores and MSLQ Posttest Scores (n=68)*

MSLQ posttest score	<i>F</i> score	<i>p</i> -value
Self-regulation scale	.134	.875
Motivation section	.484	.618
Learning Strategies section	1.007	.371
Total posttest score	.622	.540

### **Summary of findings**

This summary will synthesize the findings about changes in biological evolution understandings, evidentiary reasoning, and self-regulation. In conclusion, students demonstrated improvements in biological evolution understandings.

A similar conclusion is found regarding evidentiary reasoning. Students demonstrated improvements in evidentiary reasoning, including students in lower tracked biology courses. It was found that performance on daily tasks designed to practice evidentiary reasoning did have a significant affect on evidentiary reasoning scores. However, students did not demonstrate a

strong ability to use evidentiary reasoning in discussion forums or in daily task sets when scaffolding was withdrawn.

Additionally, it was found that initial self-regulation did not predict success in using the online instructional unit. The online instructional unit did not promote self-regulation to a significant degree. The planning, monitoring, and reflecting sheets which were designed to promote self-regulation also failed to promote self-regulation to a significant degree.

Finally, a review of student perceptions indicates that approximately one third of the students that participated in this study displayed a consistent, negative attitude towards the online instructional unit. Conversely, approximately one third of the students that participated in this study were positive about their experiences with the online instructional unit. Examination of student perceptions across all topics showed the persistence of this pattern, with one third of students generally negative about learning online, using discussion forums, and practicing evidentiary reasoning, while one third of students were generally positive.



## CHAPTER 5: DISCUSSION

The previous chapter presented the findings for the five research questions investigated by this study. The purpose of this study was to evaluate the effectiveness of an online instructional unit designed according to the PERSON framework for promoting biological evolution understandings, evidentiary reasoning, and self-regulation. Eight key elements have been included in the design of the PERSON framework. The key elements include:

*Foundational Knowledge; Simulation Study; Analyze and Extend; Case Study; Social Discourse; Scaffolding of Self-regulation; Scaffolding Evidentiary Reasoning; and Evaluation.* In this chapter I bring together the findings from each research question and connect the findings to the literature and propose explanations for these findings. In addition, I will address characteristics of the participants of this study that may have influenced outcomes.

### **Promoting Biological Evolution Understandings**

The BEAM was designed with specific items to assess content knowledge and others designed to assess evidentiary reasoning through the application of content knowledge. Participants in this research study demonstrated significant improvements of biological evolution understandings on BEAM scores from the pretest to the posttest. This increase, coupled with the large effect size, supports the assertion that the online curriculum successfully promoted biological evolution understandings with high school students. While the PERSON framework is intended to be a holistic approach to instructional design, the elements that most directly promoted biological evolution understandings are *Foundational Knowledge, Analyze and Extend, Simulation Study, and Case Study*. It can be claimed that these elements did effectively promote biological evolution understandings. These findings are consistent with other research to test the feasibility of innovative biology curricula. A study by Cetin and Nisanci (2010)

compared a traditional method of teaching environmental science with the *Conscious Individual-Environment Unit*, a student-centered, constructivist approach that utilized computer assisted instruction and problem-based learning to develop environmental awareness, content knowledge, and science process skills during a 5-week intervention. This investigation found that 9<sup>th</sup> grade biology students taught with the *Conscious Individual-Environment Unit* showed significant improvement relative to peers in a control group ( $p=.002$ ) on posttest measurements of content knowledge. A study of 58 high school students conducted by Wilson, Taylor, Kowalski, and Carlson (2010) compared use of the 5E instructional model (Bybee et al., 2006) with traditional methods of science instruction in two randomly assigned groups. Students receiving the innovative 5E instruction performed significantly better ( $F=4.570$ ,  $p<.05$ , Cohen's  $d= 0.47$ ) than the control in measures of science knowledge, scientific reasoning, and construction of scientific understandings. Further, a study of college anatomy students that compared blended with traditional instruction demonstrated that students given 43% of theoretical instruction via asynchronous online delivery performed significantly better ( $p<.001$ ) on the course exam than their peers who received all theoretical instruction in a face-to-face setting (Pereira, 2007). Like the current investigation, these studies designed instruction to utilize motivating, student-centered problem solving to effectively promote content knowledge acquisition. Unlike these studies, the current investigation did not compare implementation to a control condition.

The findings from this investigation are also consistent with research to test the feasibility of online learning environments. A pilot study of this curriculum found that it successfully promoted biological evolution understandings in an online learning environment with another sample of high school students (Marsteller & Bodzin, 2015). Seventy-one tenth grade students in a high-tracked biology class demonstrated significant improvement in mean BEAM scores from

pretest to posttest ( $p < .001$ , Cohen's  $d = 1.56$ ). However, students in the pilot study did not meet local standards of performance for items designed to assess evidentiary reasoning. Additionally, responses to surveys revealed that students in the pilot study overwhelmingly desired a greater degree of face-to-face interaction with the instructor and peers and more immediate feedback relating to questions and formative assessments.

While acquisition of content knowledge in online learning environments has been addressed, it is necessary to examine the *Social Discourse* element of the PERSON framework in relation to the research literature. Most students in the pilot study and in the current investigation stated a preference for more interaction with the instructor and peers. A study by Ong-art and Jintavee (2016) examined the efficacy of an online learning community, the *Community of Inquiry* framework in the context of applied Thai traditional medicine instruction. A sample of 39 university students demonstrated significant improvement on measures of problem solving from a pretest to posttest ( $t = 2.140$ ,  $p = .03$ ). The findings from this study support the assertion that developing a sense of social connectivity among learners promotes problem solving. Though not a study of science instruction, Raspopovic, Cvetanovic, Medan, and Ljubojevic (2017) explored student perception of the *Social Learning Environment*, a computer supported collaborative learning approach to promoting social discourse in blended and fully online college courses. Blended courses combined face-to-face direct instruction with Web-based problem-solving activities. Student responses to a survey indicated that the *Social Learning Environment* was perceived to promote communication with the instructor as well as between peers. Additionally, students reported increased motivation for collaborative work when using the *Social Learning Environment*. This study focused on student perceptions and did not report learning outcomes. However, student perceptions from this study revealed that in

order to promote positive student perceptions of social interactions in online learning environments, a highly structured approach to promoting communication is likely necessary. While the PERSON framework acknowledges the benefits of social discourse between online learners, and provides opportunity for such interactions, neither the current study nor its pilot provided as much social interaction as was desirable for participating students. In the current iteration of the curriculum, the only avenues for social discourse were the discussion forums, which contained minimal scaffolding. Contradictory evidence was found in a study conducted by Gündüz, Alemdağ, Yaşar, and Erdem (2016) that reported a lack of social contact between students using discussion forums. Students were able to create posts in discussion forums without necessarily interacting with peers. This study examined the effects of using an online problem-based learning approach for university-level Turkish language instruction. A sample of 234-distance education students showed positive outcomes on performance tasks related to course content, with 78.07% of student work receiving a grade of “high achievement.” This online instruction was effective in spite of limited social interactions. Students in the current research study have demonstrated significant improvements in learning outcomes related to biological evolution understandings, but did not have desirable levels of social interaction. The existing community environment in participating classrooms should be considered. This research did not collect data describing the degree or quality of social interactions in each class prior to implementation of this unit. It is possible that existing social norms within each community impacted social interactions in unforeseen ways. Several students expressed reluctance to participate in forums due to fear of judgment or annoyance at peer behavior. This may reflect patterns of behavior consistent with previous classroom norms. In consideration of findings in the research literature, it can be argued that the *Social Discourse* element of the

PERSON framework has not been effectively designed and implemented to promote meaningful and productive discourse in either curriculum iteration at this time.

While demonstrably improved biological evolution understandings are consistent with findings of other researchers, the degree of improvement, relative to standards of success remains questionable. An examination of test performance revealed that students only achieved what would be considered acceptable levels of performance on *Quiz and Test* items. Acceptable performance is defined by the standard for a passing grade in the school where the study was conducted. In this case, acceptable performance is 70%. Overall average posttest scores only earned 26% of total possible points; whereas average scores on *Quiz and Test* items were 73% of total possible points; average scores on *Academic Prompts for Evidentiary Reasoning* items were 32%; average scores on *Performance Tasks for Evidentiary Reasoning* items were 13%. The range of scores should be considered to provide a more complete perspective on student performance. Total posttest scores ranged from 3-49% of total possible points; average scores on *Quiz and Test* items ranged from 20-100% of total possible points, with 43% of students having scored better than 70% of total possible points; average scores on *Academic Prompts for Evidentiary Reasoning* items ranged from 0-80% of total possible points, however only one student scored better than 70%; average scores on *Performance Tasks for Evidentiary Reasoning* items ranged from 0-41% of total possible points.

The students' academic performance levels might be explained by the difficulty of the evolutionary biology content. Evolution is a difficult and conceptually complicated subject (Baumgartner & Duncan, 2009; Burton & Dobson, 2009; Van Dijk & Reydon, 2010). Understanding biological evolution demands fluency with concepts across the discipline of biology and other science content areas including chemistry, geology, and paleontology

(Hermann, 2013; Kampourakis & Zogza, 2009). While specific aspects of biological evolution are prone to high school students' misunderstandings (Dougherty, 2011; Heddy & Sinatra, 2013; Isaak, 2005; Pobiner 2012; van Dijk & Reydon, 2009), it is unclear that the persistence any of these specific misunderstandings caused poor student performance. An example of a common misunderstanding that was evident in this study relates to human origins. One BEAM assessment item (see Appendix A, number 15) asked students to evaluate primate phylogeny, including humans, from similarities of cranial capacity. Consistent with literature that identifies misunderstandings about human origins relative to modern primates (Dougherty, 2011; Heddy & Sinatra, 2013), six students (8.2%) mentioned "humans evolving from monkeys" or similar statements, however those students did not score significantly different from their peers on this item or overall. Since there is not a demonstrably significant impact resulting from common misunderstandings, and student performance on *Quiz and Test* items met acceptable standards, it is possible that items designed to assess evidentiary reasoning were particularly challenging.

### **Promoting Evidentiary Reasoning**

Participants in this research study demonstrated significant improvements on scores for BEAM items designed to assess evidentiary reasoning from the pretest to the posttest. This increase, coupled with the large effect size, supports the assertion that the online curriculum successfully promoted evidentiary reasoning with high school students. The elements of the PERSON framework that most directly promote evidentiary reasoning are *Analyze and Extend*, *Simulation Study*, and *Case Study*. These elements of the PERSON framework most likely promoted evidentiary reasoning. These findings are consistent with other research about high school students' use of scientific process skills, such as evidentiary reasoning. Leonard, Speziale, and Penick (2001) conducted a study comparing the implementation of a high school

biology curriculum designed to promote scientific inquiry skills. Sixteen teachers across the United States taught both the *Biology: A Community Context* and a traditional curriculum to separate classes of students during one whole school year. Students receiving the intervention curriculum performed significantly better than the control group on posttest measures of conceptual understandings and science process skills. The study conducted by Wilson et al. (2010) mentioned in the previous section demonstrated that an innovative curriculum effectively promoted scientific reasoning, and construction of scientific understandings better than traditional methods of instruction.

In this study, average scores on *Academic Prompts for Evidentiary Reasoning* items were 32% of total possible points; average scores on *Performance Tasks for Evidentiary Reasoning* items were 13% of total possible points. Average scores on *Academic Prompts for Evidentiary Reasoning* items ranged from 0-80% of total possible points and average scores on *Performance Tasks for Evidentiary Reasoning* items ranged from 0-41% of total possible points. When defining acceptable performance as 70%, only one student achieved acceptable performance on *Academic Prompts for Evidentiary Reasoning*; and no students achieved acceptable performance on *Performance Tasks for Evidentiary Reasoning*. Two possible explanations for the poor level of performance are considered below. First, high school students are inexperienced with evidentiary reasoning (Maloney & Simon, 2006), and second, the BEAM does not use familiar assessment types, and introduces confounding elements when assessing student performance.

In order to consider the first explanation, a subgroup analysis of student performance on BEAM items designed to assess evidentiary reasoning was conducted (see Table 8). Students' scores were divided relative to the average pretest score for evidentiary reasoning items. The students with below average pretest scores had a larger gain on the posttest items for evidentiary

reasoning than students with above average pretest scores. However, students with below average pretest scores earned fewer total points on posttest items designed to assess evidentiary reasoning compared to peers with above average pretest scores. While the mean scores for students with below average pretest scores remained below their peers, there was considerably greater improvement. This indicates that students did learn evidentiary reasoning skills in the course of the investigation, but perhaps there was an additional factor contributing to poor outcomes.

Literature that discusses the development of assessments aligned to NGSS asserts that most school-based testing is knowledge oriented, rather than performance-based (Pellegrino et al., 2014). It is possible that the poor student performance on BEAM items designed to assess evidentiary reasoning resulted from a lack of familiarity with these assessment item types. In fact, performance task items on the posttest resulted with a mean of 2.81 of 22 possible points (13%). However, even academic prompts, which are expected to be more familiar in a typical school setting, only resulted with a mean of 3.18 of 10 possible points (32%) on the posttest.

High school and university level biology teachers were consulted when validating the design of the BEAM items and assessment standards. However, expectations among teachers were inconsistent as to what defined a complete answer, especially in multi-part questions. For example, BEAM item number 9 asks students to “explain why evolution may be described as either a process or the result of that process. Support your explanation with examples.” Some teachers noted that some students in lower-tracked classes could have difficulty with compound questions. These classroom teachers explained that they did not ask lower tracked students compound questions at any time in their class. The design of the BEAM uses compound questions for all of the items assessing evidentiary reasoning. It is possible that students



participating in this investigation have little or no experience answering compound questions.

Consideration must be given to the role of scaffolding used by the PERSON framework to promote students' abilities to display evidentiary reasoning skills. The PERSON framework includes an element for *Scaffolding Evidentiary Reasoning*. Scaffolding, however, was used in the learning stages related to *Analyze and Extend* element, but not in the *Evaluation* element. Additional findings from this investigation offer further evidence that students participating in this curriculum may have developed evidentiary reasoning skills but were unable to demonstrate those skills adequately. The findings of student use of evidentiary reasoning in discussion forums (see Table 8) indicate that 68% of discussion posts did not supply any evidence at all, and only 6% used evidence to support scientific assertions. Support for student use of evidence in forums came from explicitly prompting students to use evidence and from the instructor suggesting modifications and additions after students wrote initial responses. It is likely that neither of these strategies were effective at promoting use of evidence. Additionally, student responses to survey items about using discussion forums indicate a high level of frustration with this task which indicates that use of the discussion forum was more challenging than was appropriate for this population of students. Student frustration with discussion forums further supports the need to re-evaluate the implementation of the *Social Discourse* element of the PERSON framework. Social discourse is meant to provide support and motivation for students as they acquire new skills. The opportunities for social discourse provided in this iteration did not adequately support or motivate student participants.

Student performance on the formative assessments of evidence based reasoning showed a decline in performance that corresponds to the level of scaffolding provided (see Table 10). When lesser scaffolding was provided, students did not score as well. Existing literature

supports the importance of scaffolding complex tasks for learners (Lee, Linn et al., 2010; Linn et al., 2003; Resier, 2004). When given highly structured scaffolding (e.g. choices for answers), students were able to select the correct answer an average of 96.5% of the time. When provided with reduced scaffolding (e.g. multiple-choice items were replaced with fill-in the blank items), performance fell to averages of 62.0% and 63.1%. These items remained structured, but required student to supply correct terminology. As the level of scaffolding declined to hints and reminders about the correct use of evidentiary reasoning, performance fell to averages of 43.3%, 44.7%, and 40.8%.

This suggests that the population of students represented by participants may have an optimal level of scaffolding that allows them to develop evidentiary reasoning skills. It can further be speculated that these students require a longer time at a given level of scaffolding before progressing to the next, less structured level. The second level of scaffolding, where students provided their own terminology in fill-in the blank items, is possibly the optimal level of scaffolding for this population. Zero students scored below 70% for the question set with the first level of scaffolding. For the question sets with the second level of scaffolding, 54% and 51% of students earned below 70% of possible points. While for question sets with the third level of scaffolding, 79%, 83%, and 67% of students earned below 70% of possible points. Vygotsky (1978) described the zone of proximal development as cognitive development through engaging in tasks that learners can only accomplish with support. Tasks that learners can accomplish independently do not promote cognitive growth. Therefore, the first level of scaffolding is not challenging enough to develop the evidentiary reasoning abilities of students, but the third level of scaffolding does not provide enough support. The second level of scaffolding likely provides the most appropriate challenge for students in this population. This

does not mean that these students should never be expected to demonstrate evidence based reasoning without significant scaffolding, only that they must receive appropriate support for the length of time necessary to develop these skills. This contention is supported by a study conducted by McNeill, Lizotte, Krajcik, and Marx (2006) that found 7<sup>th</sup> grade students who received fading instructional supports for creating scientific explanations performed significantly better on posttest assessments than peers who received continuous levels of support throughout an 8-week intervention.

Returning to a consideration of student performance on BEAM items designed to assess evidentiary reasoning, it becomes apparent that more structured assessment items are likely necessary for students in lower tracked biology courses. The PERSON framework provided support for student learning from the element *Scaffolding Evidentiary Reasoning*. Scaffolding for evidentiary reasoning was included in the *Analyze and Extend*, *Simulation Study*, and *Case Study* elements. This support, however, was not included the elements of *Social Discourse* and *Evaluation*. Questions in discussion forums and the BEAM may need to be broken into components reflective of and consistent with appropriate levels of scaffolding. Supporting complex assessment items may allow students to better display newly acquired knowledge and skills.

### **Promoting Self-Regulation**

Participants in this research study did not demonstrate significant improvement on scores for MSLQ items designed to assess self-regulation from the pretest to the posttest. This lack of significance, coupled with the small effect size, demonstrates that the online curriculum designed according to the PERSON framework did not successfully promote self-regulation with high school students. The PERSON element of *Scaffolding of Self-Regulation* was not effective.

Other research about the development of self-regulation suggests a possible explanation for this outcome. Chang (2005) found that the use of reflective journals and study time records for 28 students in a one-semester web-based college course demonstrated improved measures of responsibility and confidence as measured by a pre and post-test comparison of MSLQ scores. An additional study by Chang (2007) utilized a similar web-based self-monitoring form with students in another online college course. Students using the self-monitoring form in this study demonstrated significantly better academic performances and motivational beliefs compared to their peers in the control group. Reflective journals were investigated as a method to develop self-regulation in a face-to-face high school chemistry course (Al-Rawahi & Al-Balushi, 2015). Sixty-two students participated in an 8-week instructional unit. Thirty-two students were taught to use reflective journaling to develop self-regulation. The researchers compared MSLQ scores of students using reflective journals to a control group. Students in the treatment group demonstrated significantly better self-regulation scores than peers in the control group. A study conducted by Şen, Yılmaz, and Geban (2015) investigated the effects of an inquiry-based curriculum on the development of self-regulation with 115 11<sup>th</sup> grade chemistry students during a semester-long intervention. Students were divided into two groups that received the intervention curriculum and two groups that received a traditional approach to instruction. After the intervention, students in the treatment groups demonstrated significantly better measurements of self-regulation compared to peers in the control groups.

While the studies cited above demonstrate various effective methods for promoting self-regulation, it is noteworthy to draw attention to the length of time used for these implementations. Both studies by Chang (2005 and 2007) as well as the study conducted by Şen, Yılmaz, and Geban (2015) were conducted over the course of a semester. The briefest of these

studies was conducted by Al-Rawahi and Al-Balushi (2015) over an eight-week period. By contrast, this investigation was only five days long. Jakubowski and Dembo (2004) have argued that the development of self-regulated learning is time-consuming. Winne and Stockley (1998) claim that developing expert-level skills in self-regulation requires 85% of a student's formal learning time. It is likely that this investigation was not conducted over a long enough period of time to noticeably promote self-regulation among participants.

### **Achievement of Students in Lower Tracked Biology Courses**

A comparison between the pilot study and the current study may be used in order to consider the achievement of students in lower tracked biology courses. Consistent with other studies in the literature presented below, students in both districts are placed in academic ability tracked classrooms based on prior course grades and standardized test scores. The pilot study was conducted with higher tracked high school biology students in a demographically similar neighboring school district. The BEAM was used in identical form in both curriculum implementations and the biological evolution content was the same in both instances. However, students in the pilot study were primarily tenth grade students, compared to ninth grade students in the current study. Additionally, the curriculum implementation was modified to include scaffolding for evidentiary reasoning and self-regulation in the current study. Finally, the curriculum implementation in the pilot study was distributed across 12 class periods of 45 minutes each (a total of 540 minutes) while the current study was carried out over 5 class periods of 90 minutes each (a total of 450 minutes).

It can be determined that students tracked in a lower level biology course showed improvement in biological evolution understandings (a gain of 46.8% on the BEAM posttest compared to the pretest). They did not show as much improvement as students tracked in a

higher-level biology course (a gain of 68.7% on the BEAM posttest compared to the pretest).

The subset of BEAM scores from the current study addressing evidentiary reasoning was compared to a matching subset from the pilot study. The limitations in comparing the participants in the current study with participants from the pilot study have been discussed previously. Students tracked in a lower level biology course showed improvement in items designed to assess evidentiary reasoning (a gain of 63.1% on the BEAM posttest compared to the pretest). They did not show as much improvement as students tracked in a higher level biology course (a gain of 82.5% on the BEAM posttest compared to the pretest).

Findings comparing students in lower tracked courses with peers in higher tracked courses are consistent with existing literature. Collins and Gans (2013) conducted a longitudinal study of academic tracking among 9,000 elementary students in Dallas, Texas. Students' standardized test scores, classroom behavior, and identification of students in need of special education were used to determine student placement in academic ability tracked classrooms. Findings indicate that students in high tracked classes had significantly higher gains than peers in lower tracked classes. Analysis of data about approximately 3,000 middle school students from the Longitudinal Study of American Youth (Hoffner, 1992) demonstrated that students in lower tracked science and math classes show less improvement than peers in higher tracked classes. A study examining the development of energy concepts among 108 eighth-grade students (Kulo & Bodzin, 2013) found that students in low track classes demonstrated significant improvement in energy content knowledge, but still had lower mean scores on assessments than peers in higher tracked classes. Another study conducted by Bodzin (2011) examined the impact of a geospatial information technology-support curriculum on understandings of land use change and geospatial thinking. This study found that students in low track classes demonstrated significant

improvement in understandings of land use change and geospatial thinking, but still had lower mean scores on assessments than peers in higher tracked classes. Studies in the published literature tend to support that students in lower tracked classes consistently demonstrate less academic improvement than peers in higher tracked classes.

### **Struggling Learners in Online Learning Environments**

Data from this investigation may be used to further define a subset of participants that can be characterized as struggling learners. Struggling learners lack strategies to regulate their own learning (Hodges, & Kim, 2010; Jakubowski & Dembo, 2004). Motivation to learn is a feature of self-regulation. Struggling learners experience motivation primarily as extrinsic (Matuga, 2009). Perceiving motivation as primarily extrinsic negatively affects a student's ability to learn (Giesbers et al., 2014; Matuga, 2009; Rakes & Dunn, 2010). Extrinsically motivated students are less cognitively engaged in the classroom and experience decreased learning outcomes (Yen, Tuan, & Liao, 2011). Consequently, struggling learners have been characterized as not successful in traditional learning environments. However, these students make up a considerable proportion of growing enrollments in K12 learning environments (iNACOL, 2013; Queen, Lewis, & Coopersmith, 2011). The PERSON framework was designed in consideration of literature that describes methods of supporting struggling learners. While all participants in this study were in low tracked biology courses, there was no method at the time of implementation to identify struggling learners.

I have sought a post facto method of identifying struggling learners using the data collected during this investigation with the hope that future research may uncover diagnostic criteria that may be used prior to instruction. First, I noticed a preponderance of negative comments from some students on the survey responses. Many students cited both positive and

negative aspects of their experiences with the online curriculum. Yet there were 17 students that made negative comments for nearly every survey item. After identifying these “pessimistic students” with negative attitudes towards the online curriculum, I sought to examine other data points in search of a pattern.

BEAM gain scores of “pessimistic students” were compared with Evidence Based Reasoning formative assessments, Planning, Monitoring, and Reflecting sheets, and MSLQ scores for the self-regulation scale. Scores for each student were compared to total mean scores for all participants, with the exception of PMR scores, which were qualitative categories (Poor, Developing, and Proficient). Students with below average scores on data sources were identified. Ten students (59% of “pessimistic students”) had below average BEAM gain scores. Nine students (53% of “pessimistic students”) had below average self-regulation scale scores. Eight students (47% of “pessimistic students”) had below average formative EBR scores. Additionally three students were categorized as poor on the PMR sheets. Four students were identified as having below average scores on at least three of these four criteria. Data from the four students is present in Table 15. Student #1 had a BEAM gain score and self-regulation score that were nearly average, but had low scores on other criteria due to not completing assigned tasks. Student #2 has the lowest scores on all criteria. Student #2 was also observed off-task during class time and posted song lyrics in response to a discussion forum post. Student #3 had a low BEAM gain score and a low self-regulation score, but scored the highest of this subset of students on formative EBR tasks and was categorized as proficient for PMR. Student #4 had the highest self-regulation score within this subset, but had low scores for the other criteria.



Table 15.

*Data from Potential Struggling Students*

Student	BEAM gain <sup>a</sup>	Formative EBR <sup>b</sup>	MSLQ self-regulation scale <sup>c</sup>	PMR
#1	3	0*	2.83	Poor
#2	0	0**	1.42	Poor
#3	1	17	1.67	Proficient
#4	2	9	3.92	Poor

\* student #1 completed 1 of 6 EBR assignments

\*\* student #2 completed 0 of 6 EBR assignments

<sup>a</sup> total sample mean = 3.10, SD = 2.70

<sup>b</sup> total sample mean = 20.30, SD = 8.11

<sup>c</sup> total sample mean = 3.01, SD = 0.69

Examination of survey responses from this sample of students did not reveal any strong patterns. Students #1 and #2 did not complete work. On survey responses student #1 wrote “nothing” as the answer to questions about what was best about interacting with peers and the teacher. Student #2 claimed to be most frustrated by “all of it” when learning online. In a response to a survey item about using evidence, student #2 wrote “I didn’t like it because being on the computer gave me a weird feeling like angry anxiety.” Student #3 appeared to complete formative tasks, but was unable to translate that effort into success on the BEAM. On survey responses this student wrote that learning online “was hard and confusing...I’d get distracted pretty easily,” and “I didn’t learn much.” Student #4 wrote “I don’t like classes on computer. I like the teacher teaching in front of class better.” This student also described the online curriculum as “hard,” frustrating,” and “confusing.”

Within this small sampling of participants there are no unifying criteria that can identify struggling students. Students #1 and #2 did not complete much of the assigned work. Students #3 and #4 did appear to complete assigned work, but were apparently frustrated by the online learning environment. It is not clear if these students were typically unsuccessful in school, or if they were unsuccessful as a result of this intervention.

Among this subset of the participants there is not a clear pattern of low self-regulation as measured by the MSLQ. This would suggest that the MSLQ measurement of self-regulation is not sensitive to characteristics that predict success or struggle with this online curriculum. Other scales of the MSLQ were reviewed, such as internal and external goal orientation, and also found to lack significance as predictors for this online curriculum. It is possible that modifications to the MSLQ require refinement to improve its sensitivity in a high school settings, or that some other diagnostic tool is required to provide a more accurate assessment of self-regulation.

Self-regulation is a multi-faceted construct. Self-regulation is the ability of students to be responsible for metacognitive, motivational, and behavioral learning processes (Kitsantas & Zimmerman, 2009). In a meta-analysis of online learning environments, Zimmerman and Tsikalas (2005) found that courses supporting planning, implementation, and reflection produce successful learning outcomes. This finding is reflected in the current investigation. The PERSON framework used the element *Scaffolding of Self-Regulation* primarily to support the metacognitive skills of planning, monitoring, and reflecting on daily learning tasks. Based on the pilot study, it was hypothesized that metacognitive skills were of greater immediate importance to student behavior than motivation. The pilot study found students willing to work, but unsure of how to organize their time and learning strategies. Student surveys from this

investigation revealed that, at least among the 17 “pessimistic students,” there was a lack of motivation that precluded a need for metacognitive strategies.

Students’ pessimism may be due to perceptions of content (Hill & Brown, 2013). However, it has not been found that a lack of acceptance of evolutionary theory impairs student engagement. Student perceptions of evolutionary biology have been studied at the high school and college level. A study that examined the perceptions of eleven college biology majors used the Measurement of Acceptance of the Theory of Evolution (MATE) questionnaire to gauge acceptance of evolution (Hokayem & BouJaoude, 2008). Even among college biology majors in this sample, one student did not accept evolution and three remained skeptical. A study by Woods and Scharmann (2001) examine the attitudes of 518 high school science students towards evolution and logical thought as measured by the Woods-Scharmann Evolution Inventory. Results of the inventory found that 35% accept evolution as a scientific concept, 31% did not accept any part of evolution, 6% accepted evolution with conditions, and 29% were unsure of their level of acceptance. In spite of the small percentage of students that accepted evolutionary theory, nearly 80% of the students agreed that it should be taught in high school. This finding is confirmed by a study that examined the perceptions of 33 high school students in a conservative community that found 80.0% of students agreed that they liked learning about evolution in class (Donnelly, Kazempour, & Amirshokohi, 2009). This included all of students that accept evolution to be true and 66.7% of students that do not accept evolution to be true according to the MATE questionnaire. These finding indicate that perceptions of evolutionary biology content are independent of personal beliefs about evolution.

If the content of this curriculum is not a likely factor impairing motivation, it must be considered that students that fail academically may lack motivation in general (De Castella,

Byrne, & Covington, 2013). The curriculum designed according to the PERSON framework attempted to provide a motivationally supportive learning environment in accordance with findings in the literature. Hill and Brown (2013) argue that motivating instruction focuses on specific, proximal goals that a learner believes are both important and within their power to achieve. Street et al. (2012) identified instructional design that makes information perceptible, creates a welcoming environment, and to promotes interaction among students as motivating. Of these design aspects the curriculum studied in this investigation focused on proximate, achievable goals, perceptible information, and a welcoming learning environment. However, student belief of the importance of learning goals and interaction among students were not as strongly represented.

It was necessary to develop the curriculum for this investigation in accordance with state and local learning objectives. Presenting these objectives in a meaningful way for all students created some challenges. The PERSON framework was designed according to constructivist learning theories. Constructivist learning theories are a way to engage students and make learning more meaningful (Killian, et al., 2014; Rice, 2006). The ability for students to work at their own pace and to engage with content according to their prior knowledge and learning styles is consistent with constructivist learning theories (LaPrade et al., 2011; McLoughlin, 2002). Consistent with this finding, self-pacing was mentioned by 22% of survey respondents as one of the most beneficial aspects of this online curriculum. Student-centered learning allows students to organize learning into meaningful contexts. Interactive, complimentary activities allow individual learners to address unique interests and needs. Online learning environments can offer the flexibility necessary to support student-centered learning (Hannafin & Land, 1997). Students engaged in other online learning environments have reported in a survey that student-

centered learning environments promote greater learning satisfaction (NSSE, 2010). Additionally, student-centered online learning environments promote higher retention rates among secondary students than comparable teacher-centered environments (Killian, et al., 2014; LaPrade et al., 2011). These findings from the literature suggest that while self-pacing was evident as a positive aspect of this implementation of the PERSON framework, it did not adequately support student-centered learning practices. Students were not offered the flexibility to pursue their unique interests and needs. In school districts in states where there are high-stakes testing (like Pennsylvania), there is very little flexibility with regards to the content that must be covered. There are practical issues with regards to how to design for customized learning at the individual level. All students must meet standardized content standards within the time constraints of set academic periods.

Since it is not always possible to adhere to state and local learning objectives while promoting a personally meaningful engagement with content, social interaction can be viewed as an opportunity to improve motivational context for learning. Social interaction with peers in online learning environments promotes better academic outcomes (Moreillon, 2015; Muilenburg & Berge, 2005). A survey of online learners found that a lack of social interaction negatively effected learning (Muilenburg & Berge, 2005). More meaningful analysis of course content occurs when collaborating with peers than when a student works individually (Linn et al., 1998). Further, social interactions with peers have been found to improve engagement in online learning (Rice, 2006). The current implementation of the curriculum designed according to the PERSON framework did not provide adequate opportunity for students to interact with their peers. The discussion forum was the only aspect of this curriculum that utilized the *Social Discourse* element of the PERSON framework. Review of survey responses shows that many students did

not appreciate the discussion forums. Some students claimed to have not used discussion forums at all. Other students explained that they were reluctant to expose themselves to judgment from their peers. In order to serve struggling learners, the *Social Discourse* element of the PERSON framework must be redeveloped in a manner that supports motivation.

## CHAPTER 6: IMPLICATIONS AND RECOMMENDATIONS

The purpose of this study was to determine the effectiveness of a new theoretical framework for designing an online curriculum to promote biological evolution understandings, evidentiary reasoning, and self-regulation based on constructivist, student-centered learning theories. I found that the curriculum designed according to the PERSON framework effectively promoted biological evolution understandings and evidentiary reasoning among lower academically tracked students, but that self-regulation was not significantly promoted. My findings further indicate that despite significant improvement in measures of biological evolution understandings and evidentiary reasoning, students did not achieve acceptable levels of performance according to local academic standards. Eight key elements were included in the design of the PERSON framework. The key elements include: *Foundational Knowledge*; *Simulation Study*; *Analyze and Extend*; *Case Study*; *Social Discourse*; *Scaffolding of Self-regulation*; *Scaffolding Evidentiary Reasoning*; and *Evaluation*. I concluded that it is necessary to revise the PERSON framework to incorporate findings from this research study in order to achieve greater levels of performance among lower academically tracked students.

This study represents a lengthy iterative process of design and development using design based research. I began this study trying to find a way to engage all students in higher order learning tasks aligned with recent science education reforms using an asynchronous Web-based learning environment. Many school districts today are remediating struggling learners using online environments to develop content without enough regard for the learner's needs or the technological affordances unique to online learning environments. Especially given the frequency with which school districts utilize asynchronous online learning for remediation, it is vital to develop online instruction that is stimulating, challenging, and respectful of students.

This is not a simple task, and the framework I have designed remains a work in progress. The findings from this investigation will allow me to further revise the PERSON framework to better promote content understandings, scientific process skills, and self-regulation among lower academically tracked students. I start this chapter presenting the significance of the study followed by implications. Then, I present the limitations of the study design and the findings. In the next section, I offer my case for the PERSON framework as a practical approach to designing instruction in online learning environments. In the following section, I discuss several directions for future research. Finally, I conclude by reflecting on the relationship between online learning and struggling students.

### **Significance of Study**

This dissertation evaluated the effectiveness of a new design approach to online instruction aligned with the goals of science education reform and supporting the development of self-regulation skills. Enrollment in online courses continues to increase for K-12 students, especially for students who have not succeeded in traditional learning environments (Barth, Hull, & St. Andrie, 2012; Horn & Staker, 2011; Queen et al., 2011, Watson et al., 2012). The online learning environments where these students will learn must meet the challenges of science education reform, that include teaching core content knowledge and scientific practices (NGSS Lead States, 2013). Further, while students that have struggled to succeed academically in traditional learning environments may benefit from learning online, it is necessary to support their independence (Nandi et al., 2012).

This dissertation explored the ability of online learning environments to support the higher order thinking demanded by recent science education reform documents including the NGSS and NRC Framework (NGSS Lead States, 2013; NRC, 2012). The goals of science



education reform have not been readily achieved in traditional learning environments (Burton & Frazier, 2012). Online learning environments may present an opportunity to address these demands. The PERSON framework is an attempt to create online learning that emphasizes higher-order thinking compatible with the goals of current science education reform.

This study found that students developing the higher-order thinking skills of evidentiary reasoning likely require an optimal level of scaffolding to support this learning. Students differ in their capacity to acquire new thinking skills and require scaffolding that matches their needs. Flexibility in scaffolding will be important for the continued development of the PERSON framework.

Additionally, asynchronous online learning environments demand an unusually high level of independence from K-12 students. Self-regulated learning is a set of interrelated skills associated with actively monitoring and regulating one's own learning. The PERSON framework has included support for self-regulation as a key component of the design of instruction. However, this study revealed that a 5-day unit implementation was not sufficient for students to achieve improvements in their self-regulation abilities.

Every student deserves to be appropriately supported in order to meet rigorous academic challenges. Increasingly, online learning environments are called on to serve the students most in need of support to achieve challenging goals, such as those in lower academically tracked classes. It is unacceptable to continue to place students in online courses that are neither appropriately challenging nor stimulating. The design and delivery of specific elements of the PERSON framework will be revised and redeveloped to continue in an effort to address the need for stimulating online learning that supports all learners. The elements of the PERSON framework that I propose to revise are *Scaffolding Evidentiary Reasoning*, *Scaffolding of Self-*

*Regulation*, and *Social Discourse*. Specific recommendations for these revisions are discussed below.

### **Implications**

This research study was designed to test the efficacy of the PERSON framework to promote biological evolution understandings, evidentiary reasoning, and self-regulation among lower academically tracked students. The implications for each of these aspects will be addressed in the following sections.

#### **Biological Evolution Understandings**

Biological evolution is a notoriously challenging subject, yet remains central to a well-developed understanding of biological sciences (Baumgartner & Duncan, 2009; Dobzhansky, 1973; Hermann, 2013; & Zogza, 2009). Further, biological evolution is an example of core content knowledge consistent with the goals of the NGSS (NGSS Lead States, 2013). Students in this study demonstrated significant improvements in understandings of biological evolution.

Elements of the PERSON framework that most directly promoted biological evolution understandings were *Foundational Knowledge*, *Analyze and Extend*, *Simulation Study*, and *Case Study*. *Foundational Knowledge* videos provided succinct introductions to concepts and vocabulary. Students appreciated the ability to study these videos at their own pace. This element of the PERSON framework was arguably most like a didactic lecture, which may have reduced some students' anxiety to learn in a novel situation, while providing an advantage that does not exist in a traditional classroom setting. The *Simulation Study* element of the PERSON framework allowed students to apply their newly acquired knowledge to a structured learning task. Simulations further developed the concepts introduced in *Foundational Knowledge* videos while allowing students to manipulate variables and observe results. According to constructivist

learning theories, first hand, student-centered experiences like these support and promote developing knowledge. The *Analyze and Extend* element of the PERSON framework was used to analyze data generated in the *Simulation Study* while reviewing concepts and vocabulary. These questions help students create meaning from the simulation activities while drawing connections to foundational knowledge. Finally, the *Case Study* element of the PERSON framework allowed students to situate their developing knowledge within the context of authentic scientific practices. Reading about the processes that led to scientific discoveries helped students understand how their newly acquired knowledge fits with authentic scientific practices.

The process of acquiring knowledge and using it to solve problems offers benefits for retention of that knowledge. It could be argued that basic facts could be learned faster by focusing instruction on memorization but that simulations are more engaging than memorization for struggling students and may promote deeper understandings of biology content knowledge (NGSS Lead States, 2013). For the past 35 years science education reform efforts have consistently promoted inquiry, discovery, and scientific skills as a means to develop scientific literacy (Burton & Frazier, 2012; National Research Council, 2012). In spite of these efforts, typical science instruction remains focused on the acquisition of facts. Content knowledge must be utilized in synthesis with scientific practices and crosscutting concepts. The deeper, more meaningful goals of the NGSS promote understanding, rather than just knowledge. The PERSON framework was designed to promote this sort of higher-order thinking using a constructivist, student centered approach.

Increasing enrollments for K-12 online courses has created a demand to design online learning environments that optimally promote best practices for teaching and learning in online

environments. The PERSON framework offers a potential model for designing instruction to develop and support content knowledge acquisition within the context of more sophisticated science understandings.

### **Evidentiary Reasoning**

The authors of the NGSS state that scientific practices must reflect the integration of scientific skills with discipline specific knowledge and that students must develop their understanding of scientific practices through first hand application (NGSS Lead States, 2013). One such scientific practice is evidentiary reasoning (NGSS Lead States, 2013; NRC, 2012). Evidentiary reasoning is the process of collecting and arranging information to support inferences (Pellegrino, Wilson, Koenig, & Beatty, 2014). K-12 students do not have well-developed evidentiary reasoning skills (Schalk, van der Schee, and Boerman, 2013).

Findings from this research support the claim that K-12 student do not demonstrate well-developed evidentiary reasoning skills. The elements of the PERSON framework that promoted evidentiary reasoning are *Analyze and Extend*, *Simulation Study*, and *Case Study*. Students were given opportunity to develop evidentiary reasoning skills in *Analyze and Extend* and *Simulation Study* activities and to observe authentic models of these skills through case studies. Mean student scores for items assessing evidentiary reasoning showed significant improvement from pretest to posttest. Students with below average mean pretest scores had greater gains on mean posttest scores than peers with above average mean pretest scores. The PERSON framework did not promote evidentiary reasoning to a level consistent with local standards for achievement.

While the delivery of some elements of the PERSON framework requires revision to bring evidentiary reasoning achievement levels up to acceptable standards, there is hope that it offers an approach to the design of online instruction that can be utilized to develop other

scientific process skills. Manipulating variables within simulations to generate data and answering guided questions that help construct meaning from that data, when combined with the authentic models offered by case studies can be an effective way for students to experience scientific practices. Juxtaposed against increasing enrollments for K-12 online courses the PERSON framework offers a potential model for designing instruction to develop and support scientific practices.

### **Self-Regulation**

Self-regulation of learning has been defined as the degree that students are metacognitively, motivationally, behaviorally, and actively responsible for their learning processes (Kitsantas and Zimmerman, 2009). Self-regulation has been found to positively correlate with successful learning outcomes (Archambault et al., 2010; Astleitner and Hufnagl, 2003; Hodges and Kim, 2010; Levy, 2007). While the element of the PERSON framework, *Scaffolding of Self-regulation*, accounts for the importance of self-regulation in online learning environments, this study did not demonstrate significant improvements in measurements of self-regulation. Aligned with research by Zimmerman and Tsikalas (2005) students were provided with a three-step process for developing self-regulation skills. The steps are planning, monitoring, and reflection. Mean student scores for self-regulation did not improve from pretest to posttest measurements.

Self-regulated learning requires significant time to develop (Jakubowski & Dembo, 2004; Winne & Stockley, 1998). Prior research that demonstrated significant improvements in self-regulation used interventions that lasted an entire semester (Chang, 2005; Chang, 2007; Şen, Yılmaz, and Geban, 2015) or eight weeks, in the case of the shortest intervention (Al-Rawahi &

Al-Balushi, 2015). It is likely that the current study, which was conducted over five days, was not long enough to affect change in self-regulation.

Since the PERSON framework promoted self-regulation in a manner consistent with the literature, it remains possible that the approach used is viable, but not effective in the timeframe it was applied. There is an opportunity for future research to investigate the length of time required to create a detectable change in self-regulation. In medical terms, this is known as the minimum effective dose. The argument for the importance of self-regulation in online learning environments remains compelling. It is necessary to address this critical need in conjunction with the development of best practices for teaching and learning in online environments.

### **Limitations of Study**

There were several limitations to the design of this study. First, designed based research requires a process of implementation, revision, and reiteration (The Design-Based Research Collective, 2003). This investigation is the second implementation of this curriculum, following a process of revision and redevelopment following a pilot study. In design-based research, the validity of claims is achieved as each implementation produces data that either supports previous iterations or gives cause for revision (DBR Collective, 2003). As such, the validity of this study must be viewed within the context of the continuous design research process. Second, the sample was obtained from only one suburban high school. Consequently, the generalizability of the findings is somewhat limited. Third, this study lacked sufficient participants to allow adequate between group comparisons. As stated previously, comparisons between participants in the current study placed in low academic track biology courses and participants in the pilot study are tenuous at best. These two groups of participants, while in demographically comparable school districts, are not in the same grade and have not been subject to the same

curricula prior to intervention. Additionally, the current study was conducted over five, 90-minute class periods, while the pilot study was conducted over 12, 45-minute class periods. These variances in implementation may account for differences in learning outcomes.

Another significant limitation of this study is the use of the BEAM as a criterion of learning outcomes. The BEAM was designed to measure curriculum sensitivity (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). Assessment items were aligned to the content and learning activities of the curriculum this study sought to assess. While current recommendations for educational research emphasize the importance of such alignment (Lee et al., 2010; Slavin, 2008), this may limit the ability of the findings from this study to be generalized beyond the scope of this implementation. In order to reduce potential researcher bias, design-based research methodology collects data from multiple sources such as learning artifacts, surveys, tests, and observations (DBR Collective, 2003). In this study multiple sources of data were used to triangulate reliable claims supported from multiple perspectives.

Finally, it must be acknowledged that the PERSON framework was created to design effective online science instruction, but this study was implemented with students in a classroom setting. While online learning in a lab setting is a legitimate use of online learning resources, findings from this study cannot be utilized to make claims about students learning in fully online learning environments outside of lab settings. Working with students in a classroom allowed the researcher to make observations during implementation, as well as to provide immediate technical support not typically available in asynchronous environments. However, since the participants were not necessarily experienced learners in asynchronous environments they may have experienced unforeseen difficulties due to adapting to a novel learning environment. Additionally, asking students to complete learning activities online while in a room with their

peers may have introduced social distractions that would not exist outside of the classroom setting.

### **Directions for Future Research**

This section will present a future research agenda based on this study's in order to promote more effective supports for students learning in asynchronous environments. Three key elements of the PERSON framework are presented as areas of research: *Scaffolding Evidentiary Reasoning*, *Scaffolding of Self-regulation*, and *Social Discourse*. *Scaffolding Evidentiary Reasoning* is discussed in two parts, as the need to further refine understanding of the optimal level of scaffolding and as the need to provide appropriate scaffolding in assessments. *Scaffolding of Self-regulation* will be discussed in relation to identifying the time frame of implementation necessary to affect meaningful changes in students' abilities. Finally, *Social Discourse* will be discussed as an element of the PERSON framework in need of considerable revision.

#### **Scaffolding Evidentiary Reasoning**

*Scaffolding Evidentiary Reasoning* is one of the eight key elements of the PERSON framework. Findings from this study indicate that students demonstrated significant improvement on measurements of evidentiary reasoning, but that performance did not meet local standards of performance. Two possible explanations for these findings are presented for consideration as future directions for research. First, that an optimal level of scaffolding can be identified for participating students. Second, that scaffolding of evidentiary reasoning should be included in the summative assessment for this curriculum and that refinement of the BEAM to include scaffolding for evidentiary reasoning should be investigated.

Findings from this research study offer evidence that students may have developed



evidentiary reasoning skills but were unable to adequately demonstrate those skills. Student performance on the formative assessments of evidence based reasoning correlated with the level of scaffolding provided. This suggests that participants may have an optimal level of scaffolding for the development of evidentiary reasoning skills. Additionally, these students may require longer time at a more structured level of scaffolding before progressing to a less structured level. Students should receive appropriate support for the length of time necessary to develop these skills. Future research can investigate the optimal level of scaffolding of evidentiary reasoning in online learning environments, as well as a method to allow students to progress to less structured levels of scaffolding. Progression may proceed according to a schedule, or according to metrics of student performance. Research may be able to identify an optimal period of time for a student to utilize a given level of scaffolding. Conversely, a mastery approach could allow individual students to progress from more structured levels of scaffolding to less structured levels as they demonstrate competency.

Student performance on BEAM items designed to assess evidentiary reasoning indicates that more structured assessment items are likely necessary in order for students in lower tracked biology courses to effectively demonstrate newly acquired evidentiary reasoning skills. In the curriculum studied in this investigation, scaffolding was used in the learning tasks and formative assessments but not in the summative assessment. Scaffolding for evidentiary reasoning was included in the *Analyze and Extend*, *Simulation Study*, and *Case Study* elements of the PERSON framework, but not included in the element of *Evaluation*. Items in the BEAM may need to be repurposed to include appropriate levels of scaffolding consistent with the needs of struggling learners. Future research should disentangle developing student skills from assessments in such a way that the BEAM can capture all levels of evidentiary reasoning skills, rather than relying

solely on a level of mastery. The current design of the BEAM assesses evidentiary reasoning without any scaffolding. This requires students to have mastered evidentiary reasoning at a level that does not require scaffolding in order to demonstrate their knowledge. BEAM assessments for evidentiary reasoning could be redesigned to represent various level scaffolding, allowing the BEAM to accurately measure the level of evidentiary reasoning skills for each student.

### **Scaffolding of Self-Regulation**

Findings from this research study indicate that the PERSON framework did not successfully promote self-regulation with lower academically tracked high school students. Research literature demonstrating successful promotion of self-regulation suggests that a longer period of implementation is required. Several such studies were conducted over the course of a semester (Chang, 2005; Chang, 2007; Şen, Yılmaz, & Geban, 2015). The briefest study that demonstrated significant improvement of self-regulation was conducted over an eight-week period (Al-Rawahi & Al-Balushi, 2015). This research study was conducted over five days. Future research can identify the influence of length of time supporting self-regulation on measurable changes to students' self-regulation skills. There may be differences in the length of support required in online or traditional learning environments that could be explored. Additionally, length of support for self-regulation may have an optimal time frame or frequency of intervention.

### **Social Discourse**

Student responses to survey items about using discussion forums indicated a high level of frustration with this task. The discussion forum was quite challenging for lower academically tracked students. As the discussion forum was the only part of this curriculum representative of the *Social Discourse* element of the PERSON framework, future research can explore expanding

the role of social discourse in online learning environments. The design of the PERSON framework intended for the *Social Discourse* element to provide support and motivation for students as they acquire new skills. Students may require a greater degree of meaningful interactions with peers. Future research could explore collaborative problem solving as a method of promoting meaningful peer interactions. Social interaction with peers and the course instructor may be examined to identify optimal frequencies of interaction, as well as what types of interactions best promote motivation.

### **Last Words**

As the number of K-12 students enrolled in online courses has increased in the U.S.A. (Barth, Hull, & St. Andrie, 2012; Horn & Staker, 2011; Queen, Lewis, & Coopersmith, 2011) it has been found that students with the least success in traditional classroom settings are disproportionately represented in these environments. Sixty-two percent of school districts use online courses for credit recovery (Watson et al., 2012). Success in school is often defined by a relatively narrow set of criteria. The students that are least able to meet those criteria require important support that has yet to be identified. If such support has been identified it has not been provided to a meaningful degree, otherwise all students would succeed in school. I argue that the main impediment to supporting these students is an inaccurate or incomplete understanding of the complex reasons why these students do not succeed in school.

Many definitions are used to label a student as at-risk of failing in school (e.g., Hill & Brown, 2013; Vesely, 2013). However, these labels are used in a loose, inconsistent manner (Worley, 2010). I suggest the term “struggling learners” can be used to indicate students that have been placed in lower tracked courses because of previous course grades or standardized test

scores. This terminology moves away from the inconsistency of “at-risk” towards a practical definition that can be used for the design of learning environments.

The PERSON framework attempts to address the needs of learners who differ in their levels of perseverance, readiness to avail themselves of learning opportunities, and aptitude for particular content matter (Zimmerman & DiBenedetto, 2008). Constructivist, student-centered learning can offer stimulating online learning environments, provided that appropriate supports are in place for struggling learners. The nature of appropriate support remains under investigation and will likely be multi-faceted and complex. Different students likely struggle in different ways and will require a variety of supports and the ability to access and select from those supports as appropriate. Ultimately, the design of online learning environments may offer individualized support. This may likely create a fundamental advantage of online learning compared to traditional learning environments. I hope to provide a worthy contribution toward this goal.

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## **Appendix Index**

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Appendix F: Plan, Monitor, and Reflect organizer sheet Rubric

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## Appendix A: Biological Evolution Assessment Measure (BEAM)

### Definitions:

Read the supplied definitions and select the correct word from the choices listed below. (1 point each)

1) All of the members of a group capable of interbreeding and producing offspring that can also reproduce.

- A. Tribe
- B. Species**
- C. Population
- D. Community

2) A genetically determined characteristic of a living thing.

- A. Trait**
- B. Fitness
- C. Quality
- D. Variation

3) The ability of a trait to help an individual to survive and reproduce in a certain environment.

- A. Fitness**
- B. Variation
- C. Selection
- D. Adaptation

4) A hypothesis supported by lots of data that can be used to make predictions.

- A. Law
- B. Rule
- C. Theory**
- D. Corollary

5) Some individuals in a population are better able to survive and reproduce than others.

- A. Traits
- B. Species
- C. Mutation
- D. Selection

**Short Response:**

In your own words, provide an answer to the following questions.

6) When a large, old tree is cut down in the forest it creates an opportunity for seedlings on the forest floor to grow. There are both seedlings from the old tree and seedlings from other nearby trees present.

What resource(s) will these seedlings compete for?

What traits would you predict the most successful seedling might have to outcompete its neighbors for those resources? (2 points)

Scoring criteria: Response must indicate one or more resources seedlings will compete for (1 point), as well as indicate traits the seedlings will display to help them compete for each of the resources described (1 point). 2 points total

Correct: Seedlings will compete for sunlight and water. The most successful seedlings will be able to grow tall faster than their neighbors, as well as grow roots faster.

Incorrect: Seedlings must compete to survive. They could release a chemical to poison their neighbors.

7) Charles Darwin probably never heard the word “gene” in his lifetime. However, the *Theory of Evolution by Natural Selection* was supported and expanded by scientists studying genetics in the twentieth century.

How has the scientific field of genetics supported the *Theory of Evolution*?

Explain how incorporating new scientific discoveries into an existing theory make it either stronger or weaker. (3 points)

Scoring criteria: Responses must explain that genetics was not part of the original *Theory of Evolution* as described by Darwin (1 point), but has helped confirm Darwin's statements about traits by determining that traits come from genes (1 point). A theory that can incorporate new discoveries is made stronger because further evidence supports its ability to make accurate predictions (1 point). 3 points total

Correct: Darwin didn't know about genes, but he wrote about traits. Traits come from genes. The *Theory of Evolution* was made stronger by adding information from genetics that helps it make predictions.

Incorrect: Darwin didn't know about genes, so when genes came along it made everybody wonder if he was actually right. He was. New discoveries always change old discoveries, so that makes old theories weaker because they didn't know everything the first time.

8) Based on the *Theory of Evolution*, explain why humans have useless body parts such as tailbones or wisdom teeth. (2 points)

Scoring criteria: Responses must use the words "vestigial structure" (1 point) to describe body parts that are of little or no use to modern organisms, but may have been useful to our ancestors (1 point). 2 points total

Correct: Humans have useless body parts, called vestigial structures, because they may have been useful to our ancestors.

Incorrect: Humans have useless body parts because we have always had them, they're just there.

9) Explain why evolution may be described as either a process or the result of that process. Support your explanation with examples. (3 points)

Scoring criteria: Responses must indicate that among biologists evolution has two meanings. First, evolution refers to a series of processes, such as natural selection over time (1 point). Second, evolution refers to the products of the process of evolution (1 point). Modern animals

have evolved from their ancestors (process) but can also be described as “evolved” animals. Examples should refer to the process and the product (1 point). 3 points total

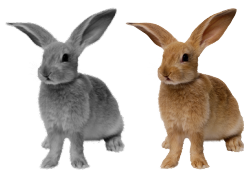
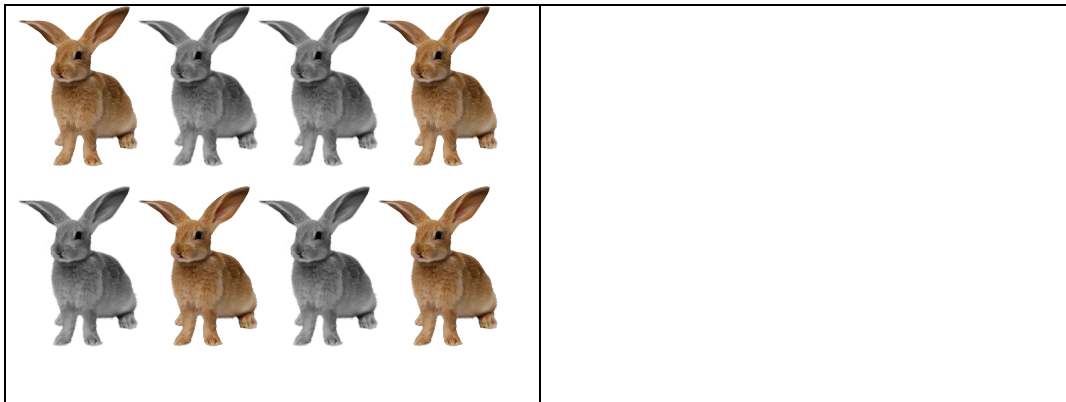
Correct: Scientists use the word evolution in more than one way. Evolution is what happens over time as natural selection changes populations, like if birds with camouflage gradually increase in number until most of the population is camouflaged. Evolution also means the things that result from evolution. The camouflaged bird population is an evolved population.

Incorrect: Scientists use the word evolution in more than one way. Physicists talk about the evolution of stars, and biologists talk about plants and animals evolving. Only biologists are talking about the same kind of evolution as Darwin wrote about in *The Origin of the Species*.

**Problem Solving:**

Follow the directions within the questions for each of the following items.

10) Observe the graphic below showing a population of rabbits. Then drag the clip art elements into the second frame to show what the population might look like after a winter with a lot of snow. (1 points)



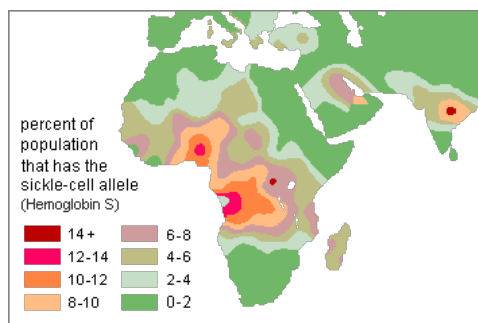
Explain what happened to this population of rabbits. Refer to the graphic you created to explain what happened.

Scoring criteria: The explanation should refer to the influence of the environment on the fitness of individuals within a population (1 point). 1 point total

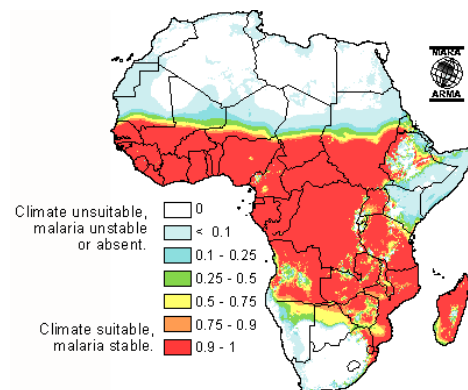
Correct response: In an environment with lots of snow it would be expected that white rabbits are camouflaged and better able to survive than brown rabbits. The white rabbits would have more offspring the following year, causing more white rabbits to be found in the population.

Incorrect: Because of the snow there was not enough food, so many rabbits died.

11) Observe the two graphs presented below. Use this information to make an argument for the relationship between the sickle-cell allele and the incidence of malaria among human populations in Africa. (4 points)



[http://anthro.palomar.edu/synthetic/images/map\\_of\\_sickle\\_cell\\_frequencies.gif](http://anthro.palomar.edu/synthetic/images/map_of_sickle_cell_frequencies.gif)



<http://www.mara.org.za/images/picdistr.gif>

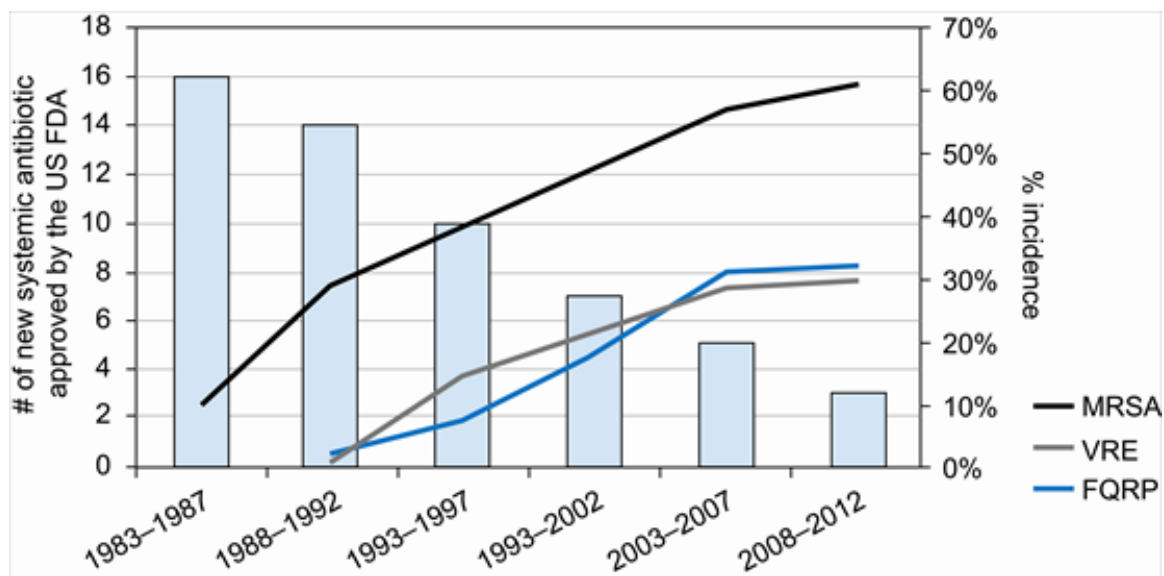
Scoring criteria: Responses should acknowledge that malaria is an environmental factor (1 point) that causes selective pressure on the human population (1 point) resulting in the increased fitness of individuals with the sickle cell allele (1 point). Responses must refer to both graphs as evidence (1 point). 4 points total

Correct: Areas in Africa with the highest rates of the sickle cell allele also have high rates of malaria infection. The sickle cell allele must cause some trait that is beneficial in an environment with malaria. There is selective pressure that causes this allele to spread.



Incorrect: There are parts of Africa where malaria is stable and parts of Africa where lots of people have the allele for sickle cell.

12) The figure below illustrates the number of new antibiotics approved by the FDA and the incidence of MRSA. Use this evidence on incidence rates for the bacteria MRSA, VRE, and FQRP to explain the role of new antibiotics in controlling bacteria populations. (5 points)



<http://www.medicinescomplete.com/mc/rem/2012/images/c115-fig-115-1.png>

Scoring criteria: Responses should acknowledge that incidence of bacterial infections have been increasing (1 point) while the numbers of new antibiotics approved by the FDA have been decreasing (1 point). Responses should acknowledge that bacteria are a population capable of responding to selective pressure, resulting in a change in that population's genes (1 point). As the population has changed, it has been necessary to develop new antibiotics for which bacteria have no adaptations (1 point). As fewer antibiotics are approved, there are fewer effective treatments for bacteria, and consequently more bacterial infections (1 point). 5 points total

Correct response: Bacteria incidence has increased over the past thirty years, while the number of antibiotics has decreased. Bacteria can adapt to their environment, like any other organism. If their environment has a toxic chemical in it, some mutants may be resistant to the chemical. There will be more mutants in the future, so those antibiotics won't work anymore. There need to be new antibiotics to stay ahead of the adaptations of the bacteria.

Incorrect response: Antibiotics kill bacteria or stop them from multiplying. More drugs help us kill more bacteria, but without new drugs the bacteria will survive.

### Analysis & Explanation:

13) You are a field zoologist preparing a report for the Department of Wildlife. You have noticed that among a population of birds known as ptarmigans, some individuals molt (replace feathers) seasonally to have a brown coat in summer and a white coat in the winter. The other members of the population have a brown coat all year. The ptarmigans live in an area with predators such as wolves, foxes, and hawks. Select the graph that shows the predicted white and brown members of the population plotted against the provided snowfall data set over the course of 10 years.

Explain what happened to the population of ptarmigans in the space below. **Support your explanation with data from your graph.** (4 points)

Select from choices of pre-made graphs...

Scoring criteria: Student has selected the graph with labeled axis, snowfall data, and both brown and molting ptarmigans (1 point). Responses should show that following years with high snowfall, there are a higher proportion of molting ptarmigans (1 point). The explanation should indicate that molting ptarmigans have an advantageous trait that allows them survive and reproduce better than brown ptarmigans (1 point). However, this trait has little effect in years with little snowfall, as there is less environmental pressure on that trait (1 point). Specific points on the graph should be referenced. 4 points total

Correct response: Correct graph selected. "Ptarmigans that are white in the winter can hide from predators better than brown ptarmigans. So, in years with lots of snow, such as year 5, there will be more white ptarmigans breeding and having white offspring. But, in years without so much snow, like year 6, it may be a disadvantage to be white, so there may not be as many white birds to breed those years."

Incorrect response: Correct graph not selected. "Ptarmigans have an advantage in a snowy environment. They have adapted to the snow. So, when it snows a lot more of them avoid predators and reproduce."

14) Imagine you went on vacation to a pair of islands in the middle of the Atlantic Ocean. On the larger island you find that all of the squirrels have short tails. On the smaller island you find that all of the squirrels have large, bushy tails.

1. Write a hypothesis that could explain these observations.
2. Design an experiment to test your hypothesis. Be sure to identify dependent and independent variables, as well as any important controls. (5 points)

Scoring criteria: Response identifies a valid hypothesis with a testable explanation for the difference in squirrel tails (1point). The designed experiment accurately tests the hypothesis as stated (1 point). The experiment is limited to testing one correct dependent variable (1 point). The experiment has clearly identified a correct independent variable (1 point). At least one control is stated (1 point). 5 points total

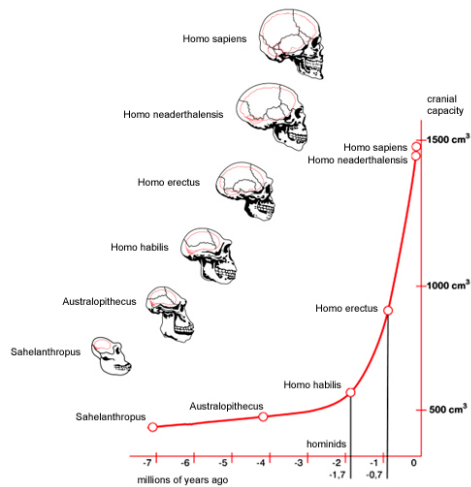
Correct: Hypothesis: The difference in tail length on the two islands results from different types of predators found on each island. To test this hypothesis it would be necessary to observe as many squirrels as possible on each island and see what kinds of predators attack them. The independent variable would be the squirrels' tails. The dependent variable would be the type of predators found on each island. One control would be the time of day observations are made.

Incorrect response: The squirrels are probably different on the two islands because maybe one set of squirrels swim and the other climb trees. The experiment will involve looking at a good map and measuring the distance of each island from the mainland, and then each island from the other. The squirrels on the island closest to the mainland should be most like the normal squirrels you find there.

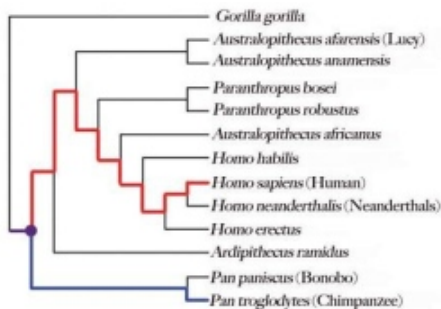
15) Observe the two figures presented below.

A. Based on this evidence, make a prediction about the likely cranial capacity of modern gorillas (*Gorilla gorilla*) and modern chimpanzees (*Pan troglodytes*). (4 points)

B. Explain some factors that may limit your ability to make accurate predictions with this data. (1 points)



[https://ib-biology2010-12.wikispaces.com/file/view/hominid brain cavity size.jpg/296833098/hominid brain cavity size.jpg](https://ib-biology2010-12.wikispaces.com/file/view/hominid+brain+cavity+size.jpg/296833098/hominid+brain+cavity+size.jpg)



[http://www.thebottomlineonline.org/polopoly\\_fs/1.2541349!/image/1050472890.jpg\\_gen/derivatives/landscape\\_260/1050472890.jpg](http://www.thebottomlineonline.org/polopoly_fs/1.2541349!/image/1050472890.jpg_gen/derivatives/landscape_260/1050472890.jpg)

Response criteria: Responses must refer to figure showing cranial capacity among hominids to explain that cranial capacity of hominids has increased over time (1 point). Responses must refer to the cladogram of hominid ancestry to differentiate between the evolutionary proximity of chimps and humans, and the relative distance between gorillas and humans (1 point). Responses must predict that gorillas would have smaller cranial capacity than chimps (1 point) but that both should have smaller cranial capacity than humans (1 point). 4 points total

Responses must provide at least one reason the provided data does not allow them to make accurate predictions (1 point).

Correct response: In the graph showing cranial size it is obvious that the closer in time to humans, the bigger the cranial capacity. For example, Australopithecus has a cranial capacity of about 500 cubic centimeters and lived 4 millions years ago, but homo erectus has a cranial capacity of about 750 cubic centimeters and lived 700,000 years ago. If you look at the next graph it show the family tree of humans. The further to the left a split is, the further back in time the family “split.” Gorillas split off from the family tree before chimps did. I would predict that both chimps and gorillas have smaller cranial capacity than modern humans. I would also predict that chimps have a larger cranial capacity than gorillas. Maybe the chimps have 300 cubic centimeters, and the gorillas only have 250 cubic centimeters. But it is possible that those predictions are not accurate, because gorillas and chimps have evolved on their own since they split from the human family tree.

Incorrect response: Gorillas probably have a bigger brain than chimps. Gorillas are much bigger than chimps, so their heads should be bigger, too. There is no data about the size of any ape or monkey skulls, so it is difficult to predict the cranial capacity of any of them.

## Appendix B: Modified Motivated Strategies for Learning Questionnaire

### Part A. Motivation

The following questions ask about your motivation for and attitudes about this class. **Remember there are no right or wrong answers, just answer as accurately as possible.** Use the scale below to answer the questions. If you think the statement is very true of you circle 5; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 5 that best describes you.

1	2	3	4	5
not at all true of me				very true of me

1. In a class like this, I prefer course material that really challenges me so I can learn new things.
2. If I study in appropriate ways, then I will be able to learn the material in this course.
3. I believe I will receive an excellent grade in this class.
4. I'm certain I can understand the most difficult material presented in the Web-based readings for this course.
5. Getting a good grade in this class is the most satisfying thing for me right now.
6. It is my own fault if I don't learn the material in this course.
7. The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.
8. I'm confident I can learn the basic concepts taught in this course.
9. If I can, I want to get better grades in this class than most of the other students.
10. I'm confident I can understand the most complex material presented in the videos in this course.
11. In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.
12. If I try hard enough, then I will understand the course material.
13. I'm confident I can do an excellent job on the assignments and tests in this course.
14. I expect to do well in this class.
15. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
16. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.
17. If I don't understand the course material, it is because I didn't try hard enough.
18. I'm certain I can master the skills being taught in class.
19. I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.
20. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.



## Part B. Learning Strategies

The following questions ask about your learning strategies and study skills for this class. **Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible.** Use the same scale to answer the questions. If you think the statement is very true of you circle 5; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 5 that best describes you.

1	2	3	4	5
not at all true of me				very true of me

21. When I study the Web-based readings for this course, I outline the material to help me organize my thoughts.
22. During class time I often miss important points because I'm thinking of other things.
23. When reading for this course, I make up questions to help focus my reading.
24. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.
25. When I study for this class, I practice saying the material to myself over and over.
26. When I become confused about something I'm reading for this class, I go back and try to figure it out.
27. When I study for this course, I go through the readings and my notes and try to find the most important ideas.
28. If course readings are difficult to understand, I change the way I read the material.
29. When studying for this course, I read my notes and the Web-based readings over and over again.
30. I work hard to do well in this class even if I don't like what we are doing.
31. I make simple charts, diagrams, or tables to help me organize course materials.
32. Before I study new course material thoroughly, I often skim it to see how its organized.
33. I ask myself questions to make sure I understand the material I have been studying in class.

34. I try to change the way I study in order to fit the course requirements and the instructor's teaching style.
35. I often find that I have been reading for this class but don't know what it is all about.
36. I memorize key words to remind me of important concepts in this class.
37. When course work is difficult, I either give up or only study the easy parts.
38. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
39. When I study for this course, I go over my notes and make an outline of important concepts.
40. I make lists of important items for this course and memorize the lists.
41. Even when course materials are dull and uninteresting, I manage to keep working until I am finished.
42. When studying for this course I try to determine which concepts I don't understand well.
43. When I study for this class, I set goals for myself in order to direct my activities in each study period.
44. If I get confused taking notes in class, I make sure I sort it out afterwards.

## Appendix C: The Online Instruction Questionnaire

Item

Number

Question

- 1) How was your online learning experience about biological evolution different from your other learning experiences in biology class?
- 2) What was the most frustrating part of learning with the Website materials?
- 3) What was the best part of the online learning experience?
- 4) If you were to take a course that was entirely online, what could make the class more enjoyable for you?
- 5) If you were to take a course that was entirely online, what would you expect to be most frustrating for you?
- 6) What was the best part about interacting with other students with the online discussion forums?
- 7) What was the most frustrating part about interacting with other students with the online discussion forums?
- 8) What was the best part about interacting with the teacher with the online discussion forums?
- 9) What was the most frustrating part about interacting with the teacher with the online discussion forums?
- 10) Describe your experiences using evidence and data to support scientific claims or arguments before this online learning experience. Were you asked to use data or evidence to explain answers to questions in class or for classwork? Were you asked to use data or evidence to back up your opinions?

- 11) How did using the EBRF flowchart impact your understanding of how to use evidence to make an argument?
- 12) How did the daily *practicing evidentiary reasoning* problems impact your understanding of how to use evidence to make an argument?
- 13) How did the participation of the instructor in discussion forums impact your understanding of how to use evidence to make an argument?
- 14) Please provide any additional information you would like to share about your experiences with the online instructional unit.

## Appendix D: Evidence Based Reasoning Framework Rubric

EBRF element	2 pts	1 pt	0 pts
data	cites meaningful, focused data	cites data that is apparently arbitrary or unfocused	does not cite any specific data
evidence	states accurate, thorough relationship between data	states inaccurate or incomplete relationship between data	does not state any relationship between data
rule	states a relationship between conditions or events expected to hold in novel contexts	states a relationship between conditions or events expected to hold in limited, similar contexts	does not state a relationship between conditions or events expected to hold in novel contexts
claim	makes a statement about a specific outcome	makes a statement about a general outcome	does not make a statement about an outcome

## Appendix E: Sample Plan, Monitor, and Reflect Organizer Sheet

### Task Set 1, The Diversity of Life:

Where does genetic variation come from?

How does diversity within a population affect survival of individuals?

How do genes lead to traits of individuals and diversity within a population?

activity	PLAN: How long will this take to complete?	MONITOR: How long did this take to complete?	REFLECT: Why were the predicted and actual times different? Explain.
Introduction and Orientation video (5:34)			
Evidence Based Reasoning video (5:03)			
The Diversity of Life video (5:35)			
Discussion Board Posts			
Question Set			

**Appendix F: Plan, Monitor, and Reflect Organizer Sheet Rubric**

7-9                    *Proficient*: student demonstrates consistently high levels of self-regulation  
 4.5-6.9            *Developing*: student demonstrates development of self-regulation  
 0-4.4                *Poor*: student does not demonstrate effective self-regulation

	0	1	2	3
planning	did not complete	partially completed	fully completed with some attention to detail and accuracy <i>times for videos usually match video running time, little variation in estimation for tasks</i>	evidence of specific, thoughtful completion, detailed <i>times show development towards increasing accuracy</i>
monitoring	did not complete	partially completed <i>all times are exactly the same as planning predictions</i>	fully completed with some attention to detail and accuracy <i>most times are exactly the same as planning predictions</i>	evidence of specific, thoughtful completion, detailed <i>times reflect some variation from planning predictions</i>
reflecting	did not complete	partially completed or one or two word answers for most reflections	some ( $\leq 50\%$ ) reflections show specific detail	most ( $> 50\%$ ) reflections show specific detail

## Appendix G: Curriculum vitae

**Robert B. Marsteller**

**503 N Robinson Ave.**

**Pen Argyl, PA 18072**

**484-358-2636**

[rbmarsteller@gmail.com](mailto:rbmarsteller@gmail.com)

### **Education:**

#### **Lehigh University, College of Education**

PhD candidate, Teaching, Learning, and Technology

All coursework degree requirements completed

Dissertation title: Making Online Learning Personal: Evolution, Evidentiary Reasoning, and Self-Regulation in an Online Curriculum

2009-2017                      GPA: 3.9

#### **Kutztown University of Pennsylvania**

Masters of Education, Curriculum and Instruction

Post-Baccalaureate certification: Secondary Education, Biology

Graduated December 2006, GPA: 3.9

#### **New York University, Tisch School of the Arts, Maurice Kanbar Institute of Film and TV**

BFA, Honors                      Graduated January 1999, GPA 3.7

### **Teaching Certification:**

Pennsylvania Biology 7-12, level II

### **Refereed Publications:**

Marsteller, R. B., & Bodzin, A. M. (2015). The Effectiveness of an Online Curriculum on High School Students' Understanding of Biological Evolution. *Journal of Science Education and Technology* 24(6), 803-817. doi: 10.1007/s10956-015-9565-5

### **Refereed Conference Presentations:**

Marsteller, R., & Bodzin, A. (2016, January). Scaffolding Evidentiary Reasoning in an Online High School Biology Curriculum. Paper Presentation at 2016 Association for Science Teacher Education (ASTE). Annual meeting, Reno, N.V.

Marsteller, R., & Bodzin, A. (2015, January). The effectiveness of an online curricular approach on high school students' understanding of biological evolution. Paper



Presentation at 2015 Association for Science Teacher Education (ASTE). Annual meeting, Portland, O.R.

Marsteller, R., Farina, W., & Bodzin, A. (2013, October). Teaching science online: Critical issues for student learning. Roundtable session presented at 2013 Association for Science Teacher Education Northeast Region (NE-ASTE). Annual meeting, Cornwall, N.Y.

Garrigan, S., Marsteller, R., & Stotz, M. (2013, February). Augmented reality in education. Poster presentation presented at 2013 Pennsylvania Educational Technology Expo & Conference (PETE & C). Annual meeting, Hershey, P.A.

Marsteller, R., & Butler, N. (2005, April). Spatial and temporal examination of chemical, physical, and biological parameters in Muhlenberg Lake. Poster presentation at 2005 Commonwealth of Pennsylvania University Biologists (CPUB). Annual meeting, Millersville, P.A.

### **Instructional Experience:**

#### **Instructor**

**Fall 2016**

Taught TLT 426: Science in PreK- 4 Grade at Lehigh University. Revised existing syllabus, prepared and facilitated in-class lab and learning activities, lead instruction, assessed learning, and provided students with constructive feedback to help them develop as pre-K- 4 science teachers.

#### **Instructor**

**Fall 2015-**

#### **Spring 2016**

Taught biology lecture and lab courses (BIO 110L, BIO 111, BIO 111L) at Lehigh Carbon Community College. Prepared syllabi, lectures and lab activities. Created and graded weekly assignments and course assessments for students majoring in science.

#### **Co-instructor**

**Fall 2013**

Co-taught TLT 426: Science in PreK- 4 Grade at Lehigh University. Worked with lead instructor to revise syllabus, prepare and facilitate in-class lab and learning activities, support and lead instruction, assess learning, and provide students with constructive feedback to help them develop as pre-K- 4 science teachers.

#### **High School Biology Teacher 2013**

**Fall 2007-**

Taught high school science at Pen Argyl Area High School. Courses taught include General Biology, Lab Biology, Anatomy & Physiology, Aquatic Biology, and Environmental Science. Wrote curricula aligned with Pennsylvania State Standards. Maintained class web management with Edline. Acted as lead biology teacher. Served as advisor for the TV studio and Envirothon extra-curricular activities.

**Instructor/ Tutor  
2008**

**Fall 2004-**

Developed curriculum and taught three courses: “Science Skills,” “The History of Science,” and “Environmental Biology” for the Upward Bound Math/Science program at Kutztown University. This program provides scholastic supplementation to high school students from urban schools that have demonstrated the potential to go to college.

**Instructor  
2005/ 2006**

**Summer**

Developed curriculum and taught four courses: “Introduction to Chemistry,” “Biology,” “Reading and Writing About Science,” and “The Art and Science of Nature” for the Kutztown University Preparatory Academy. These courses were part of an eighteen-day summer enrichment program for high school students.

**Supplemental Instruction Leader**

**Spring 2006**

Organized small-group tutoring sessions for undergraduate general chemistry course at Kutztown University. Coordinated content with course professor and attended lectures weekly.

**Instructor  
Spring 2006**

**Fall 2005-**

Developed curriculum and taught “Natural History, Natural Drawing,” for a private group of five high school age home schooled students who met for two hours every week. This course emphasized observation and communication skills in the context of the natural world.

**Instructor  
Spring 2005**

**Fall 2004-**

Developed curriculum and taught, “Communicating with Moving Images” for Lehigh Valley Home School Enrichment program. This course was a weekly video production class with a dozen students, emphasizing media literacy and application to creating student projects.

**Graduate Assistant  
2005**

**Spring 2004- Spring**

Worked as graduate assistant for the Biology department; Kutztown University, Kutztown, Pennsylvania. Set up labs for introductory courses for majors and non-majors. Ran make-up sessions of labs for undergraduate students.

**Substitute Teacher  
2004**

**Spring 2002- Spring**

Worked in New York City, New York, and Allentown, Pennsylvania public schools as a substitute teacher in grades pre-K through 12.

**Service:**

**Mentor****2013-2016**

Serve as a mentor to at-risk high school students in Pen Argyl Area High School through the Families First, Round Table program.

**Other Experience:****Weight Lifting Coach****2015-present**

Coach weight lifting technique and programming to children aged 11-18.

**Aikido Instructor****2006-2011**

Taught weekly martial arts classes to children aged three to thirteen. In addition to self-defense, classes focus on developing respect, discipline, and self-confidence.

**Freelance Filmmaker****1998-2002**

Worked in various jobs in the film and television field for companies such as MTV, Nickelodeon, Comedy Central, ABC, and BBC. Jobs included production management, storyboard artist, set dresser, and production assistant, among others.

**Honors and Awards:**

Kutztown University College of Education Clinical Experience Award, 2007

Ray & Marjorie Sunderland Scholarship: recipient, 2006

Commonwealth of Pennsylvania University Biologists: Outstanding Student Award, 2005-2006

Commonwealth of Pennsylvania University Biologists: grant recipient, 2004-2005