A STANDARDS-BASED CONTENT ANALYSIS OF SELECTED BIOLOGICAL SCIENCE WEBSITES

by

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This dissertation was prepared under the direction of the candidate's dissertation advisor, Dr. David Devraj Kumar, Department of Teaching & Learning, and has been approved by the members of her supervisory committee. It was submitted to the faculty of the College of Education and was accepted in partial fulfillment of the requirements for the degree of Doctor of Education.

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ABSTRACT

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The purpose of this study was to analyze the biology content, instructional strategies, and assessment methods of 100 biological science websites that were appropriate for Grade 12 educational purposes. For the analysis of each website, an instrument, developed from the National Science Education Standards (NSES) for Grade 12 Life Science coupled with criteria derived from the Web-based Inquiry (WBI) for Learning Science instrument (Bodzin, 2005) and other pertinent published educational literature, was utilized.

The analysis focused on elucidating the appropriateness of the biology content, instructional strategies, and assessment tools of selected websites for facilitating the biological science education of Grade 12 students. Frequencies of agreement and disagreement of the content of each selected website with criteria included in the data collection instrument were used for alignment determination of the content of each website with the NSES. Chi-square tests were performed by Microsoft Excel to determine the statistical significance of differences of actual and expected 85% frequencies of alignment of the analyzed website parameters with indicators of alignment to NSES.

Chi-square tests indicated that at a 0.05 level of significance there was an overall difference between the actual and expected 85% frequencies of alignment of biology content, instructional strategies and assessment methods with website indicators of alignment with the NSES ($p < 0.05$). Chi-square tests also indicated that there was a significant difference between the actual and expected frequencies of alignment of analyzed categories (biology content, instructional strategies, and assessment methods) of the sampled websites with website indicators of alignment with the NSES ($p < 0.05$).

Major findings of this study indicated that 3 out of 4 of the analyzed content attributes, 12 out of 13 of the instructional strategies, and all the assessment methods of the researched biological science websites were less than 85% aligned with the NSES. Only 11 out of 80 (13.75%) of the analyzed websites had collective biology content, instructional strategies, and assessment methods attributes that were 85% or more aligned with the NSES. Appropriately sequenced content that fostered acquisition of fundamental biology knowledge was the only content attribute with significantly more than 85% alignment with the NSES. Provision of illustrative examples to enhance understanding of facts and/or ideas in the context of a conceptual framework was the only instructional strategies attribute that was significantly more than 85% aligned with the NSES.

Alignment of website attributes with the NSES has the potential to enhance the educational value of science websites. It is hoped that the findings of this study will motivate science website designers to comply with the NSES. Hope also exists that

educators will be motivated to engage in standards-based reform measures for promoting scientific literacy among students.

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Chapter 1: Introduction

Background of the Study

National Science Education Standards

Consensus appears to exist among members of the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Research Council (NRC) that National Science Education Standards (NSES) are necessary for reforming science education in the U.S. (AAAS, 1993; NRC, 1996). These standards coupled with Project 2061's Benchmarks for Science Literacy reflect a vision that calls for excellence in science education for all students. Inherent in the standards is the notion that all students can and should have excellent and equivalent science learning opportunities (AAAS, 1997; NRC, 1996). The notion is that all students must be given the opportunity to attain scientific literacy.

The AAAS and the NRC regard scientific literacy as the capabilities to: (a) understand the interrelationships among the natural world, technology as well as science and (b) apply scientific knowledge and skills to personal decision-making and the analysis of societal issues (AAAS, 1993; NRC, 1996). Project 2061 defines science literacy broadly with emphases on the connections among ideas in the natural and social sciences, mathematics, and technology (AAAS, 2006). The belief is that scientific literacy can only be achieved if science education reform measures are implemented by educators.

Overall, the NSES provide stringent guidelines for organization of educational systems (AAAS, 1993; Moreno, 1999). These standards provide recommendations for effective classroom instruction and guidelines for age-appropriate curriculum development, student learning, authentic assessment procedures, as well as professional development programs for teachers (AAAS, 1993; Moreno, 1999; Slater et al., 2001). Specifically, the standards clearly stipulate the subject matter that students should know and they describe what students should be able to do (NRC, 1996).

One important directive of the NSES is that didactic classroom instruction that focuses on memorizing science facts must be de-emphasized. As an alternative, the mandate is for instruction to emphasize engagement of students in inquiry-based learning that will foster understanding of science. The insistence on inquiry-based learning is partially based on the recognition that science is essentially a question-driven, open-ended process. Therefore, students must have personal experience with scientific inquiry to understand the fundamental aspects of science (Linn, Songer, & Eylon 1996; NRC, 1996).

World Wide Web

The World Wide Web (Web) is an amazing educational resource that is easily accessible to many groups of educators and learners. It hosts a plethora of websites that provide learners with a rich range of learning materials for enhancing science education (Nikolaos, Nikolaos, Avouris, Dimitracopoulou, & Daskalaki, 2001). Additionally, the Web is a powerful medium that can be used easily for publishing educational research findings and instructional material (Nikolaos et al., 2001).

It has been widely accepted that the Web is a powerful educational tool (Neo & Neo, 2008). In fact, there are educational researchers who characterize the Web as an active learning environment that supports creativity (Becker & Dwyer, 1994). According to Thuring, Mannemann, and Haake (1995), the Web encourages exploration of knowledge and browsing behaviors that are strongly related to learning. Tuvi and Nachmias (2001) explained that the Web's advanced graphical tools and computational power allow scientists, educators, and students to visualize scientific data and processes in ways that allow a deep understanding of natural phenomena. Daugherty and Funke (1998) reported that the information on the Internet is usually current, presented in meaningful contexts, and affords students the opportunity to explore more widely a topic, interest, or fact.

Hannafin, Hill, Oliver, Glazer, and Sharma (2003), declared that the Web provides learners with authentic learning contexts, opportunities for active learning, resources, tools, and scaffolds that can enhance learning as well as transfer of knowledge to novel situations. Hannafin et al. (2003) endorse The Little Planet Literacy project (peabody.vanderbilt.edu/ctrs/lsi/morelp.htm) that serves as one example of a context-rich, web-based activity with real situations, tools, and problems. The goal of the activity is to use problem-solving strategies to drive an automobile to a final destination using a nonlinear path. Learners are provided with a variety of tools such as rulers, protractors, and calculators. Additionally, learners manage numerous variables such as money, road obstacles, gasoline, pit stops, and different forms of currency in order to accomplish a task.

The Web displays various ways of storing and structuring information that is provided for Internet users (Nikolaos et al., 2001). Reality is that multiple representations of educational material such as text, graphics, sound, animation, and digital video are supported by websites (Alessi & Trollip, 2001). These features of the Web are deemed to be potentially beneficial to students with diverse learning styles (Guskin, 1994). The idea is that the Web has the potential to provide learners with a wide range of opportunities for learning.

Educational Websites

It is apparent that educational websites need to be appropriately designed if learning is to be enhanced in students with different learning styles. Although individuals have generally been categorized as visual, auditory, or kinesthetic learners, there is a notion that numerous learning style profiles exist. According to Price, Dunn, and Dunn (1991), individuals have predetermined learning preferences in respect of environmental, emotional, sociological, physical, and psychological learning conditions. Thus, students have diverse learning style profiles that reflect varying preferences for each learning condition. This implies a vital need for adept website designers to conceptualize differences in learning style profiles that will guide innovative website designs.

Of particular importance for biological science education, is the extensive array of biology websites that are hosted by the Web. The perception among educators is that websites are out-of-class learning modalities that provide consistent educational messages in flexible environments (Reis, Riley, Lokman, & Baer, 2000; Wall & Cox, 2000). A notion exists that websites can be used to foster collaborative efforts, create scaffolds, allow reflection, and allow students to focus on the depth rather than the breadth of a learning situation (Hung, 2001; Winnips & McLoughlin, 2001).

WebQuests.Org (http://edweb.sdsu.edu/webquest/webquest.html) provides examples of the use of scaffolds in web-based learning environments (Hannafin et al., 2003). The idea is that access to resources combined with a motivating question in a WebQuest can help students to develop higher-order thinking skills (March, 1998). Each WebQuest activity includes a task, the process for accomplishing the task, Web resources, how the task will be evaluated, and a conclusion (March, 1998). Hannafin et al. (2003) remarked that the WebQuest designs enable scaffolding and structure without restricting creativity in the appearance or content of the activity.

There is no doubt that the Web is highly rated as an educational tool that provides Internet users with accessibility to a wide range of free reference material and assessment tools that can influence learning outcomes. However, it is important to realize that use of the Web does not automatically guarantee favorable learning outcomes (Reeves, 1992). Substantial evidence exists in published educational literature to suggest that the Web must be appropriately designed to support effective instruction (Reeves & Reeves, 1997). Additional evidence implies that the Web needs to be used correctly to foster meaningful learning (Alexander, 1995; Eklund, 1995).

Specifically, science websites may be regarded as formal or informal learning environments within the spheres of influence of the NSES. The plethora of science websites provides diverse instructional resources that have the potential to enhance meaningful learning (Nikolaos et al., 2001). These resources include scientific visualizations, simulations, virtual reality, and animations that can prompt students to analyze data, compare different viewpoints on issues, formulate conclusions, and communicate findings to individuals in different locations.

Web-based Instruction

Websites facilitate web-based instruction that utilizes the resources of the Internet to create a context in which learning is supported and fostered (Daugherty & Funke, 1998). Web-based instruction facilitates active, student-centered learning. In addition, it occurs in a multi-dimensional learning environment that promotes learning, which is not limited by time or space boundaries (Lin, Liu, & Yuan, 2008). Indications are that any student who has access to a computer with an Internet connection can use global information and resources on websites to enhance learning.

Web-based instruction involves the use of web-based documents that are characterized by hypertext/hypermedia which facilitate development of structural and content-based links between pieces of information (Clavi, 1997; Nielsen, 1990). As a result, the information is presented in a non-linear manner. Several reasons exist to support the notion that hypermedia is an important advance in educational technology. One example is that hypermedia enables nonlinear access to vast amounts of information (Nielsen, 1995). Other examples are that (a) users can explore information in depth on demand (Collier, 1987); (b) interaction with the instructional material can be self-paced (Barrett, 1988); (c) hypermedia is attention capturing or engaging to use (Jonassen, 1989); and (d) hypermedia represents a natural form of representation with respect to the workings of the human mind (Delany & Gilbert, 1991).

Overall, web-based instruction appears to be a viable pedagogical option, but the complexity of hypermedia links and the regularity with which they appear throughout web-based documents can be overwhelming and distracting for learners (Lee & Calandra, 2004). Consequently, Web users may become so disoriented and/or sidetracked while trying to work in hypermedia environments that they can lose mental power, which is required for learning (Jonassen, 1989; Kenny, 1993; Romiszowski, 1990).

One advantage of web-based instruction is that students are provided with the flexibility and convenience of learning that cannot be obtained from traditional sources of information. Websites and other hypermedia environments allow students to choose which information they would like to access and when they would like to access it (Becker & Dwyer, 1994). As a result, many students search for website information in their personal domains (Kuiper, Volman, & Terwel, 2005).

Although web-based learning is convenient for students, it is important to realize that web-based instruction often lacks the direct supervision of educators. The flexible nature of web-based learning implies that educational websites need to store information that meets the requirements for national educational standards. Within the context of science courses, it is imperative for the content of science websites to be strongly aligned with the NSES.

The expectation of educators is that there should be a significant improvement in the academic achievement of science students who utilize science websites. However, the educational research findings of many studies indicate that use of the Web and other technology-based experiences do not significantly improve the academic performance of students (Clark, 1983; McKnight, Dillon, & Richardson, 1991, 1996). This awareness coupled with knowledge that the Web enables students to have accessibility to a massive network of scientific information that is not aligned with current science educational standards is daunting, especially for science educators.

Statement of the Problem

Many students in the United States rely to a great extent on science websites for education. However, usage of websites for educational purposes is a major cause of concern among educators (Leonard, 2001; Mashhadi & Han, 1996). The vast majority of information on the Internet is not subject to peer review or academic regulation (Wilkinson, Harries, Thelwall, & Price, 2003).

Although a fairly large number of science website analyses have been done and general classification schemes proposed, it is unclear to what extent the World Wide Web presently provides students with scientific inquiries that are mandated by the NSES. A notion exists that the content areas of many websites employed during technology-enhanced biology instruction in the United States are not significantly aligned with the current National Science Education Standards. According to Wilkinson et al. (2003), most websites are created for broadly scholarly reasons. This implies that the vast majority of the content of biological websites in the United States may not be aligned with the NSES.

Purpose of the Study

The purpose of this study was to analyze the biology content, instructional strategies, and assessment methods of 100 biological science websites that were appropriate for Grade 12 educational purposes. The analysis determined if biology content, instructional strategies, and assessment methods of the website sample are significantly aligned with the NSES for Grade 12 Life Science.

Research Questions

The research questions that were addressed in this study are:

1. Is the biology content of biological science websites significantly aligned with National Science Education Standards?

2. Do biological science websites utilize inquiry-based instructional strategies that align significantly with the National Science Education Standards?

3. Are the assessment methods of biological science websites significantly aligned with National Science Education Standards?

Hypotheses

Research findings about the appropriateness of utilizing websites in science education have led me to hypothesize that the content areas of biological science websites are significantly aligned with National Science Education Standards.

The hypotheses that are addressed in this study are:

Ho1: The biology content of biological science websites is not significantly aligned with National Science Education Standards.

Ho2: Biological science websites do not utilize instructional strategies that align significantly with National Science Education Standards.

Ho3: The assessment methods used on biological science websites are not significantly aligned with National Science Education Standards.

Research Design

A quantitative research design entailing a standards-based content analysis of 100 biological science websites that were designed for educational purposes was utilized for this study. Websites were selected based on a protocol described in Chapter 3 that involves AltaVista, Google, Lycos, and Yahoo Internet search engines. Data collection employed an instrument that was custom developed based on the Web-based Inquiry (WBI) for Learning Science instrument (Bodzin, 2005) and on a review of published educational literature. Frequencies of alignment and no alignment of content included in each website with criteria incorporated in the data collection instrument were used for determining the significance of alignment of each website with the NSES.

Assumption

It was assumed that the Web search engines used for retrieval of the websites provided a representative sample of the public biological websites that are hosted on the World Wide Web. This assumption is based on knowledge that websites include public web pages that are readily accessible by any web crawler.

Delimitations

This study focused on a content analysis of 100 biological science websites in order to determine if the biology content, instructional strategies and assessment methods of the website sample are significantly aligned with the NSES for Grade 12 Life Science.

Limitations

1. Only 100 websites of an extremely large number of biological science websites were analyzed.
2. Many of the analyzed websites were not specifically developed for Grade 12 biology educational purposes.
3. The data collection instrument used in this study was custom developed by the researcher based on the Web-based Inquiry (WBI) for Learning Science instrument (Bodzin, 2005) and on a review of published educational literature.

4. The data collection instrument asked 21 questions that required yes or no responses.

5. Generalization of the findings of this study must be limited to the websites that were included in the sample.

Significance of the Study

Inquiry-based instruction and use of technology are important mandates of the NSES (NRC, 1996). Research-based evidence exists to support the premise that biological science websites can facilitate inquiry-based instruction, but it is unclear to what extent the content and instructional strategies of biology websites are significantly aligned with the NSES

This study is significant because it contributes to a growing body of research on web-based education. The findings add to the limited scholarly literature that relates to the use of science websites for implementing science reform measures. Specifically, the findings help to indicate the appropriateness of the science content and instructional strategies of biological science websites for implementing inquiry-based instruction. In addition, the findings of the study have numerous implications for future large-scale analysis and evaluations of science websites.

Operational Definitions

The following terms are defined to clarify the concepts that are included in this study:

Advance organizer: An advance organizer is “introductory material at a higher level of abstraction, generality, and inclusiveness than the learning passage itself” (Ausubel, 1978). The purpose of an advance organizer is to provide context rather than content and to provide conceptual scaffolding rather than specific detail from a body of new information. Ausubel (1978) described two types of advance organizers: (a) Expository advance organizers used when learning material is completely unfamiliar, and (b) Comparative organizers used when the learning material is more familiar. These organizers provide scaffolding and highlight the principal similarities and differences between new and previously learned ideas.

Alignment: Alignment can be broadly defined as the degree to which the components of an educational system work together to achieve the desired goals of stakeholders (Case & Zucker, 2008). In this study, alignment refers to the degree to which biology content, instructional strategies, and assessment methods of biological science websites comply or agree with NSES for Grade 12 Life Science. For this research, the acceptable alignment for each analyzed item was an expected 85% alignment with the NSES

Assessment methods: Assessment methods involve use of tools such as quizzes and tests for monitoring students' academic progress (Carver, Lehrer, Connell, & Erickson, 1992).

Authentic activity: An authentic activity is coherent and meaningful, and its purpose is to help learners acquire the culture and practices of those active in the real world practice of the field under study (Brown, Collins, & Duguid, 1989).

Biology content: Biology content refers to topics stipulated by the NSES for Grades 9-12 Life Science: The cell; Molecular basis of heredity; Biological evolution; Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms (NRC, 1996).

Constructivist learning environment: A constructivist learning environment allows learners to work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities (Wilson, 1996).

Content analysis: Content analysis is a set of qualitative and quantitative methods for collecting and analyzing data from verbal, print, or electronic communication with numerous applications in education research (Kondracki, Wellman, & Amundson, 2002). According to Neuendorf (2002), content analysis is a summarizing, quantitative analysis of messages that relies on the scientific method (including attention to objectivity-intersubjectivity, a priori design, reliability, validity, generalizability, replicability, and hypothesis testing) and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented.

Distance education: Distance education is instruction delivered over a distance to one or more individuals located in one or more venues (Phipps, Wellman, & Merisotis 1998).

Higher-order thinking skills: Higher-order thinking skills refer to cognitive skills such as critical thinking skills that allow students to function at the analysis, synthesis, and evaluation levels of Bloom’s Taxonomy (Hopson, Simms, & Knezek, 2001).

Hypermedia systems: Hypermedia systems are computer-based software modules, which may combine text, images, sound, and video. These systems are designed, as non-linear, reticulate structures of linked ideas, with no predefined path to traverse when navigating through a network of information. This unique characteristic of hypermedia allows for a high degree of learner control. Therefore, learners are free to select which learning strategy or strategies are the most effective and efficient at achieving learning tasks (Wilhelm, Friedemann & Erickson, 1998).

Hypertext system: A hypertext system works like a database that stores text-based learning materials. Hypertext consists of textual information units connected by associative links and is the scaffolding on which most Web-based instruction is built. Like hypermedia, hypertext-based systems give learners freedom to access, select, search, and browse through available information in a non-linear fashion. Marchionini (1988) described a hypertext-learning environment as a self-directed, information-fluid environment with high teacher-learner interaction.

Ill-structured problems: Ill-structured problems have multiple solutions, multiple solution paths, few parameters, and contain uncertainty about which concepts, rules, and principles are necessary for their solution (Jonassen, 1997).

Inquiry: Inquiry refers to activities performed by students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996). According to the NSES, inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work (NRC, 2000).

Instructional strategies: In this paper, instructional strategies refer to carefully devised plans of action that are developed and executed to achieve specific educational goals mandated by the NSES. Eggen and Kauchak (2006) defined instructional strategies as general approaches to instruction that apply to a variety of content areas and are used to meet a range of learning objectives.

Internet: The Internet is a worldwide computer network that was begun by the U.S. government to support education and research primarily (Lee & Misser, 1999). According to Mashhadi and Han (1996), the Internet is the public "network of networks" which spans the world and can be accessed through dial-up connections or direct high-speed business links.

Multimedia systems: Multimedia systems deliver information in a computer-based presentation by integrating two or more kinds of media including text, graphics, motion video, still video, voice recognition, animation, and sound (Beckman, 1991).

National Science Education Standards (NSES): NSES provide recommendations for effective classroom instruction and guidelines for age-appropriate curriculum development, student learning, authentic assessment procedures, as well as professional development programs for teachers (AAAS, 1993; Moreno, 1999; Slater et al., 2001). Overall, the standards stipulate the subject matter that students should know and describe what students should be able to do (NRC, 1996).

Online courses: Online courses are courses in which instruction is delivered completely on the Internet.

Scaffolds: Scaffolds are tools, strategies, and guides that support students while they attempt to attain higher levels of understanding that would be impossible to achieve without assistance (Vygotsky, 1978). Scaffolds may be classified as conceptual, metacognitive, procedural, and strategic (Hannafin, Land, & Oliver, 1999).

Scientific visualizations: Scientific visualizations are representations that present scientific relationships as visual patterns and provide data-intensive descriptions of phenomena (Bodzin & Cates, 2003).

Self-regulation: Self-regulation refers to the process by which students activate and sustain cognitions, behaviors, and effects that are oriented systematically toward attainment of their goals' (Boekaerts, 1997; Zimmerman, 1994).

Simulations: Simulations are interactivities that are used to simulate and explore complex phenomena (Bodzin & Cates, 2003).

Situated cognition: Situated cognition refers to knowledge and the conditions of its use that are inextricably linked (Brown et al., 1989).

Structure: Structure is defined as an instructional strategy that frames the learning activity (Bruner, 1977; Hannafin et al., 2003).

Virtual reality: Virtual reality refers to technology that enables a user to interact with and explore a spatial environment through a computer (Bodzin & Cates, 2003).

Web-based instruction: Web-based instruction is an innovative approach for delivering instruction to a remote audience using the World Wide Web as the instructional delivery system (Khan, 1997). Web-based instruction has two popular forms: non-linear hypertext and hypermedia learning technologies. Web-based tools such as educational development tools (e.g., Blackboard™, Filamentality™, WebCTTM, and Quia™), and assessment tools (e.g., online diagnostics and testing), are components of Web-based systems. These tools may facilitate and enhance the learning process due to their media-rich environments and ability to link together several pieces of information (Gibbs, 1999).

Web search engines: The Wikipedia webpage notes that Web search engines are designed to search for information on the World Wide Web. Information may consist of web pages, images, and other types of files. Some search engines also mine data available in newsbooks, databases, or open directories. Unlike Web directories, which are maintained by human editors, search engines operate algorithmically or are a mixture of algorithmic and human input.

World Wide Web: Mashhadi and Han (1996) described the World Wide Web (Web) as "an Internet-based hypermedia initiative for global information sharing" (p. 3). According to Mashhadi and Han (1996), the Web "uses interlinked hypertext documents to find and display multimedia information, including text, color graphics, video, and audio" (p. 7).

Chapter 2 of this dissertation presents a review of selected published literature about cognitive learning theories, Internet usage, and the NSES. Chapter 3 describes the methodology that was employed in this study. Chapter 4 of the dissertation presents the results of the study in relation to the hypotheses and problem statement that were introduced in Chapter 1. Chapter 5 of the dissertation presents a discussion of the results, implications of the findings, conclusions, and recommendations for further educational research.

Chapter 2: A Review of the Literature

A review of selected published literature related to cognitive learning theories, Internet usage, coupled with National Science Education Standards (NSES) and inquiry-based instruction for enhancing formal and informal education of students is presented in this chapter. The chapter also presents a review of science education research involving content analysis. The Educational Resources Information Center (ERIC), the Scholarly Journal Archive (JSTOR), Wilson, and other electronic databases were searched in order to select articles that were specifically concerned with cognitive learning theories, Internet usage, NSES, inquiry-based instruction, and content analyses.

In addition to the database search, references of relevant articles were located and scanned to identify pertinent material. This method led to the procurement of additional articles and books. The extensive search resulted in the acquisition of journal articles, white papers, conference proceedings, and books with several relevant pieces of literature that were included in this review.

The reviewed literature on cognitive learning theories emphasized constructivism and social contexts. While, literature on Internet usage referred to terms such as computer-based-instructional technology, computer-mediated learning, distance education, educational technology, hypermedia, multimedia, online instruction, technology-enriched instruction, web-based instruction and websites. In contrast, literature on the NSES explicitly referred to life science standards and inquiry-based instruction. The reviewed studies involving content analysis included methodology and major research findings.

The reviewed literature included several relevant studies that are described in this chapter. Each study was examined to identify the participants/samples, methods of data collection, and common themes or sets of variables that appear to influence students' ability to use websites for facilitating biological science education. Additionally, each reported study was subjected to critique in order to determine the quality of the reporting and research as well as compliance with the following set of standards.

1. A clear statement of the problem.
2. Statement of intentions/purpose of the study.
3. Clear statements of hypotheses and assumptions.
4. Reference to a framework and previous research.
5. Information about the context of the study.
6. Definition of important terms.
7. Methodology is appropriate and includes a fully described research design and suitable data collection methods.
8. Sources of collected data are provided.
9. Description of population/participants and samples.
10. Establishment of validity and reliability of data.
11. Correct application of appropriate data analysis methods.
12. Clear presentation of appropriate data.
13. Discussion of findings that emerged from the data.
14. Statement(s) of limitation(s) of the study.

15. Conclusion/discussion is related to the framework and substantiated by the data.
16. Report is clearly written, logically organized, and reflects an unbiased, impartial scientific attitude.

Theoretical Framework

Cognitive learning theories postulated by acclaimed cognitivists Ausubel, Vygotsky, and the Cognition and Technology Group at Vanderbilt (CTGV) as well as the Framework for Web-Based Learning developed by Khan (1997) provided frameworks for the content analysis of websites that was done in this study. The cognitive learning theories refer to learning as an active, constructive process (Shuell, 1986; Wittrock, 1989). In contrast, Khan’s Framework for Web-Based Learning refers to eight dimensions: pedagogical, technological, institutional, ethical, interface design, resource support, online support, and course management (Khan, 1998).

A major tenet of Ausubel’s cognitive theory of learning is that prior knowledge facilitates meaningful learning (Ausubel, 1962). The central theme of Vygotsky’s theory of cognition is that social interaction is essential for cognitive development (Vygotsky, 1978). The Cognition and Technology Group at Vanderbilt theorizes that meaningful learning occurs when instruction is anchored in macro-contextual environments within videodiscs (CTGV, 1993).

Cognitive Learning Theories

A review of published literature about cognitive learning theories indicated that these theories are based on the premise that meaningful learning is active, constructive, goal-oriented, and linked to social context (Shuell, 1986; Vygotsky, 1978; Wittrock, 1989). Specifically, Ausubel’s Assimilation/Subsumption Theory (1962), Vygotsky’s Social Development Theory (1978), and the Anchored Instruction Theory formulated by the Cognition and Technology Group at Vanderbilt (CTGV, 1993) provide strong justification for the use of biological science websites to enhance the performance of students who are enrolled in biology courses.

Constructivism

The literature made it clear that the central tenet of constructivism is that learning is an active process. An existing consensus among constructivists is that knowledge and truth are actively constructed by people and do not exist outside of the human mind (Duffy & Jonassen, 1991). It is apparent that meaningful learning involves the development of frameworks or schemas in the brains of learners that provide explanatory and predictive power in variable situations (Rumelhart & Norman, 1988). This notion implies that information may be imposed on people, but understanding must come from within a person (Tam, 2000). According to Jonassen (1991), learners may conceive of the external reality somewhat differently, based on their unique set of experiences with the world and their beliefs about the experiences. The Cognition and Technology Group at Vanderbilt purported that learners may discuss their understandings with others and develop shared understandings of experiences. It is clear that the onus is on learners to justify their perceptions of reality and to establish their viability (CTGV, 1991).

Social Context and Learning Environments

Substantial evidence exists in literature on cognitive learning theories that construction of knowledge is facilitated by collaboration and problem solving that occurs in a social context within authentic learning environments. According to Jonassen (1991), learning occurs most effectively in context. He explained that context is an important part of the knowledge base associated with learning.

Based on the reviewed literature, it is very clear that problems in learning environments are important for initiating the learning process. According to Dewey (1938), it is a problem in a learning environment that leads to and organizes learning. Dewey's notion of the importance of problems for organizing the learning was endorsed by Savery and Duffy (1995), who professed that it is a learner's 'puzzlement' that creates a stimulus and organizer for learning. Tam (2000) provided further endorsement for Dewey's view by explaining that learning is determined by the complex interaction among learners' existing knowledge, the social context, and problem that needs to be solved.

Apparently, environmental stimuli or motives for learning initiate the constructivist learning process. This notion is supported by Brandon (2004) who posited that a constructivist learning environment should provide a supportive and motivating environment in which learners can interact with others while they solve problems and assess their learning. Brandon's idea also provided support for Powers and Guan (2000) who explained that active learning environments stimulate student motivation and encourage student participation in learning tasks.

Powers and Guan (2000) provided support for Hannafin et al. (2003) who endorsed the JASON project, *Education through Exploration*, which provides students with active learning environments. JASON connects students with great explorers and great events to inspire and motivate them to learn science (JASON Foundation for Education, 2010). In the JASON project, leading scientists work with middle school students in an online global community. The project challenges the student participants to apply their knowledge to real-world scenarios that scientists face every day (Schutz, 2008).

Additional evidence for the establishment of rich social contexts within authentic learning environments was provided by Zhu, Valcke, and Schellens (2008), who reported findings of a study in which they examined student perceptions, motivation, and learning strategies in a constructivist e-learning environment from a cross-cultural perspective. A parallel e-learning environment for a first-year university course was implemented for a Flemish group (n=217) at Ghent University and a Chinese group (n=165) at Beijing Normal University. The findings indicated that the Flemish students perceived the e-learning environment more positively than their Chinese counterparts. However, Chinese students' motivation and learning strategies changed significantly and moved in line with a constructivist learning approach after exposure to the e-learning experience.

Ausubel's Subsumption Theory of Learning

Ausubel (1962) theorized that meaningful learning occurs when new ideas are subsumed or assimilated into a learner's existing cognitive structure (network of knowledge) that has been established by prior learning. Based on Ausubel's Subsumption Theory of Learning, students who lack prior knowledge of a topic do not have information in their cognitive structures (schemata of their brains) with which new knowledge can be associated or anchored. The implication for instruction is that students require prior knowledge of topics that are being taught in order for meaningful learning to occur.

Ausubel’s notion of the pivotal role that prior knowledge plays in meaningful learning was supported by findings of two open-learning studies done by Portier and van Buuren (1995) with 24 and 139 university students respectively. The researchers found that students with high prior knowledge of statistics utilized more embedded support devices in web-based learning than students with limited prior knowledge (Portier & van Buuren, 1995). The interaction between prior knowledge and use of embedded support was most pronounced for processing figures and examples and for testing devices such as exercises and self-checks.

Ausubel (1978) proposed the use of advance organizers such as analogies, charts, concept maps, textual passages, videos, and other types of representations at the beginning of a lesson to provide students with relevant knowledge and an overview of a topic that is being taught. The idea is that advance organizers can facilitate the creation of new knowledge that becomes assimilated into the existing knowledge structure or cognitive framework of a learner’s brain. According to Novak (1998), advance organizers can facilitate meaningful learning by bridging the gap between new knowledge and knowledge that exists in the cognitive framework in the brain of a learner.

Vygotsky’s Social Development Theory

Existence of a Zone of Proximal Development is a central tenet of Vygotsky’s Social Development Theory (1978). Specifically, this theory is based on Vygotsky’s belief that social interaction is essential for cognitive development. According to Rice and Wilson (1999), the theoretical concept of the Zone of Proximal Development is embodied in Vygotsky’s belief that learning is directly related to social development.

Based on research findings, Vygotsky believed that a distance exists between a child's actual development as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. Consequently, he argued that cognitive development requires social interaction. Vygotsky (1978) explained that capable individuals can help students to understand difficult concepts and ideas.

The existence of a Zone of Proximal Development implies that scaffolding and appropriate sequencing of knowledge are vital during instruction for making new knowledge compatible with a learner's previous cognitive experiences (Vygotsky, 1978). This implication is further supported by Hung's declaration that learning must become a social activity in which the teacher, students, and peers work as members of a learning community to gain new experiences, garner knowledge, and solve problems together (Hung, 2001).

Scaffolding

WebQuests.Org (http://edweb.sdsu.edu/webquest/webquest.html) referenced in Chapter 1 and the Deformed Frog Mystery (http://wise.berkeley.edu/WISE/demos/frog-activity/) provide examples of scaffolding in web-based learning environments (Hannafin et al., 2003). The Deformed Frog Mystery created using the Web-based Inquiry Science Environment (WISE) scaffolds Grade 5 to 12 students in developing a rationale about why frog mutations occur (Linn, Shear, Bell, & Slotta, 1999). The activity is structured around possible questions that students might ask: "What's the problem?" "Where are the deformed frogs?" "What's in the water?" and "Why study frogs?" Within each question, structure is provided to help students organize their thinking and evaluate information.

The researchers found that students were able to successfully analyze complex scientific content with this system. In particular, low academic performers benefited greatly from cognitive engagement with the activity.

Literature on scaffolding suggests that scaffolds promote self-regulation that is essential for enhancing web-based learning. According to Winnips & McLoughlin (2001), video commentaries, Web links, and links to good examples of student work are examples of scaffolds. Hogan and Pressley (1997) proposed scaffolding by pre-engagement; establishing a shared goal; actively diagnosing the understandings and needs of learners; providing tailored assistance; maintaining pursuit of a goal; giving feedback; controlling frustration and risk; and assisting internalisation, independence, as well as generalization to other contexts.

The Anchored Instruction Theory

The Anchored Instruction Theory is based on the premise that instruction is anchored in complex problem spaces or macro-contexts that serve as environments for cooperative learning and teacher-directed mediation (CTGV, 1990). This theory implies that learners need to be exposed to appropriate video-based or other macro-contextual learning environments. Reports indicate that students who engage in active learning are deemed to gain knowledge and understanding of course content that enhances their perception of progress toward their academic goals (Anderson & Adams, 1992; Chickering & Gamson, 1987; Johnson, Johnson, & Smith, 1991; McKeachie, Pintrich, Yi-Gunag, & Smith, 1986). The implication is that effective instructional strategies are tools for promoting active learning that can enhance students' academic performance.

In the reviewed literature, the Anchored Instruction Theory and the importance of problem-based learning were supported by findings of a study done by Neo and Neo on the impact on student learning (Neo & Neo, 2008). In this study, the researchers used the web as an instructional tool in a problem-based learning environment. Specifically, the study revealed that problem-solving, analytical skills, critical-thinking skills, and learning of relevant content were enhanced among learners (Neo & Neo, 2008). The researchers noted that the problem-based learning approach emphasized the social context of the learning environment. An additional notation was that social interactions enabled students to learn with and from one another. The implication is that this type of interaction can increase learners' development of cognitive skills, knowledge, and understanding (Vygotsky, 1978).

Neo & Neo (2008) explained that a problem-based learning environment is student-centered and the students are active, autonomous learners who are immersed in their own learning processes that involve construction of knowledge. This problem-based mode of instruction contrasts sharply with a passive teacher-led mode of instruction in which learners merely receive information and knowledge (Neo & Neo, 2008).

In problem-based instruction, students are encouraged to find their own solutions to the problems based on their prior knowledge, experiences and attitudes (Neo & Neo, 2008). This instructional mode emphasizes the fact that problems must be authentic, meaningful, and relevant to the learners (CTGV, 1990; Neo & Neo, 2008). An additional emphasis is that the teacher must assume the role of facilitator or guide and support to help students to construct knowledge and solve problems (Neo & Neo, 2008; Vygotsky, 1978).

The reviewed literature on cognitive learning theories also revealed Biggs' belief that the process of learning is determined by students' approaches to learning (Biggs, 1987a; Biggs, 1987b). Indications are that individuals employ four main learning approaches: surface, achieving, deep, and deep-achieving. One belief is that an individual's approach to learning embodies motives for learning, learning strategies, and perceptions of learning tasks. Another belief is that learning approaches change according to changes in motives, strategies, and task perceptions (Biggs, 1987a; Biggs, 1987b). Biggs and Moore (1993) stated that deep and deep-achieving approaches to learning are more likely to result in better learning outcomes that surface and achieving approaches. This implies that instruction should facilitate use of deep and deep-achieving approaches to learning.

Overall, the reviewed literature on cognitive learning theories revealed several distinctive influences that affect cognitive change and learning. These influences include: (a) the learner's existing knowledge and experience; (b) the learner's predisposition to learning; (c) the learner's approach to learning; and (d) the learning contexts. Specifically, the literature provided evidence to support the view that effective instructional strategies foster engagement of students in active learning by ensuring that each student becomes involved in critical thinking, problem-solving, and construction of knowledge related to real-life experiences. The literature also indicated that active learners participate in activities such as discussions and group work that require learners to do things and think about the things they are doing (Bonwell & Eison, 1991).

Implications of Cognitive Learning Theories for Instruction

Based on the important tenets of the cognitive learning theories, the implication is that effective instruction must provide learners with a collaborative situation in which they have opportunities to use prior knowledge for the construction of new, context-specific understandings (Ertmer & Newby, 1993). Various authors have described characteristics of instruction that promote constructivism (e.g., Brooks & Brooks, 1993; CTGV, 1993; Collins, Brown, & Holum 1991; Honebein, Duffy, & Fishman, 1993). It is clear that instruction that is deemed to be effective for facilitating constructivism requires learners to collaborate and use their knowledge to solve authentic, meaningful, complex problems. Indications are that problems provide contexts for learners to apply their knowledge and to take ownership of their learning (Tam, 2000).

According to Brooks and Brooks (1993), instruction must require learners to solve good problems. These authors stipulated that a good problem: (a) requires learners to make and test a prediction; (b) can be solved with inexpensive equipment; (c) is realistically complex; (d) benefits from group effort; and (e) is regarded to be relevant and interesting by students. The notion is that good problems are required to stimulate exploration and reflection that are required for knowledge construction (Brooks & Brooks, 1993).

The constructivist perspective of learning provides justification for instruction that provides learners with collaborative opportunities. Constructivist learning theories support the notion that learners learn through interaction with others (Tam, 2000). The idea is that learners work together as peers and apply their combined knowledge as they find solutions to problems. The dialogue that ensues during collaboration provides learners with multiple opportunities to refine their understanding of events (Tam, 2000).

The theories of learning and the perspectives of constructivism that are presented in this chapter have implications for the creation of instructional principles that can specifically guide biological science instruction and the design of biological science websites (Bednar, Cunningham, Duffy, & Perry, 1992). According to Bednar et al. (1992), effective instructional design and development must be based a cognitive learning theory. Based on a review of the literature on how instructional designs relate to constructivism, Lebow (1993) proposed ‘Five Principles toward a New Mindset’ as constructivist values that have the potential to influence instructional design.

Lebow’s *Five Principles toward a New Mindset* are:

Principle 1: Maintain a buffer between the learner and the potentially damaging effects of instructional practices by:

- Increasing emphasis on the affective domain of learning.
- Making instruction personally relevant to the learner.
- Helping learners develop skills, attitudes, and beliefs that support self-regulation of the learning process.
- Balancing the tendency to control the learning situation with a desire to promote personal autonomy.

Principle 2: Provide a context for learning that supports both autonomy and relatedness.

Principle 3: Embed the reasons for learning into the learning activity itself.

Principle 4: Support self-regulated learning by promoting skills and attitudes that enable the learner to assume increasing responsibility for the developmental restructuring process.

> Principle 5: Strengthen the learner’s tendency to engage in intentional learning processes, especially by encouraging the strategic exploration of errors (Lebow, 1993, pp. 5 - 6).

Lebow’s principles (1993) have direct implications for guiding biological science instruction and the design of biological science websites. It is clear that effective educational websites and other learning environments must include rich contexts that provide learners with multiple opportunities to create meaningful knowledge and deep understanding of experiences (Hannafin, Hannafin, Land, & Oliver, 1997).

Further review of the literature revealed Willis’ Constructivist-Interpretivist Instructional Design Model that was formulated based on a comprehensive review of literature about instructional design models. It is apparent that Willis’ model can be applied to various learning strategies such as situating cognition in real-world contexts, cognitive flexible learning, and collaborative learning (Willis, 1995). The characteristics of Willis’ Constructivist-Interpretivist Instructional Design Model are:

1. The design process is recursive, non-linear, and sometimes chaotic.
2. Planning is organic, developmental, reflective, and collaborative.
3. Objectives emerge from design and development work.
4. General instructional design experts do not exist.
5. Instruction emphasizes learning in meaningful contexts (the goal is personal understanding within meaningful contexts).
6. Formative evaluation is critical.
7. Subjective data may be the most valuable (Willis, 1995, pp. 5 - 23).

Internet Usage

Educational literature is replete with evidence that the Internet has great potential for improving teaching and learning (Owston, 1997; Wallace, Krajcik, & Soloway, 1996; Windschitl, 1998). As a result, the Internet has become increasingly important to both educators and students. Akroyd, Jaeger, Jackowski, and Jones (2004) declared that the Internet has become a vital tool for course development and teaching.

Specifically, educational literature abounds with evidence of increasing use of the Internet as an information resource in K–12 education. This relates to the fact that the governments of many countries promote the use of the Internet for education. Also, there is an increase in the number of schools and classrooms that are connected to the Internet (NRC, 1996). Currently, Internet usage for education ranges from research to supplementing instruction in face-to-face classes to instruction in online classes (Akroyd et al., 2004). Wallace (2004) reported that some teachers even use the Internet as a substitute for visiting speakers.

According to Kuiper et al. (2005), the Internet provides students with more opportunities for interactive work than traditional information sources can possibly provide. The options for interactive work include navigating the Web by following content-based links between pieces of information; e-mailing the designers of websites or e-mailing other people who are mentioned on the site. The Internet also makes it possible for individuals to participate in news groups on a particular theme through websites (Kuiper et al., 2005).

Major findings of case studies done by Wallace in 2004 revealed that high school science teachers and students who participated in the studies used information on the Internet like books, library resources, and field trips. The teachers used the Internet like a television set or an overhead projector for graphic representation of content during their classes. Additionally, teachers used the Internet for organizing collaborative work in small groups.

Neo and Neo (2008) reported that the versatile supply of educational resources provided by the Internet and the World Wide Web can facilitate learner-centered learning. However, educators and policy makers have realized that computers and the Internet must be equitably distributed and used appropriately in order to fulfill the role of enhancing learning among students (Cummins & Sayers, 1995).

Cummins and Sayers (1995) reported findings of case studies in which technology-enhanced global learning networks were employed successfully in classrooms. One major finding of these case studies was that students with experience in using networks for intercultural collaboration had a competitive edge over those without similar experience. As a result, Cummins and Sayers concluded that one duty of schools is to provide all students with an equal opportunity to prepare themselves for learning from a networking environment.

Findings of three case studies on Internet usage that were done by Wallace in 2004 revealed that the three teacher participants faced common challenges that were manifested in three different ways. Four outstanding challenges experienced by these teachers were: (a) knowing the subject matter; (b) knowing what students know and can do; (c) assessing students’ work; and (d) developing a coherent progression of ideas.

One teacher participant in Wallace’s case studies wanted students to learn subject matter from their Internet work, but she lacked methods or tools to hold students accountable for their work on the Internet. As a result, she could not evaluate what the students learned. Wallace (2004) explained that the challenge of knowing subject matter and the challenge of knowing what students know and can do depends both on features of the Internet and the assignment. The findings of Wallace’s case studies imply that science teachers need to perform the usual tasks of teaching such as planning, implementing, interacting, and assessing in order to enhance learning outcomes of students. The teacher participants in these studies realized the importance of identifying and selecting Web resources that are appropriate for use in their science classes (Wallace, 2004).

Overall, studies on the effectiveness of Internet usage in education have produced results that justify the use of websites for improving students’ academic achievement (Kumrow, Vogt, & Kazlauskas, 2002). Wallace (2004) reported that a teacher participant in one of his case studies on Internet usage used the Internet: (a) as a source of variety and motivation; (b) for content that is not otherwise available; and (c) as a resource to help students learn to evaluate information and improve their critical thinking skills.

The reviewed literature on Internet usage supports the view that websites are learning environments that have multiple dimensions for enhancing learning. However, it is clear that websites should not be regarded as instructional delivery modes that can replace classroom instructors.

Although some websites have been designed to meet the needs of students in a particular grade or subject, it is highly likely that several websites, which have not been precisely constructed to meet the specific needs of learners, will be used by students (Wallace, 2004). Also, numerous websites may cause disorientation and other problems that are typically associated with hypertext (Jonassen, 1989; Kenny, 1993; Romiszowski, 1990; Wallace, 2004).

In these cases, it is the role of teachers to ensure that students use the Internet in ways that provide curricular rationality. The indication is that teachers must help students to interact with a reasonable sequence of ideas that will contribute to meaningful learning.

National Science Education Standards and Inquiry-based Instruction

National Science Education Standards

Ample evidence exists in published literature that NSES reflect a vision of science instruction by which students are aided to construct their own understanding of science concepts (AAAS, 1993). These standards have been substantially influenced by Project 2061, a long-term AAAS reform initiative to advance literacy in Science, Mathematics, and Technology (AAAS, 1993).

Project 2061 was specifically established in 1985 to provide support for allowing all Americans to become literate in science, mathematics, and technology (AAAS, 2006). In 1989, the Project 2061 panel published *Science for All Americans* with recommendations that helped to shape the NSES mandates of what all high school graduates should know and be able to do in science, mathematics, and technology (Kulm, Roseman, & Treistman, 1999).

Two important mandates of the NSES are that scientific instruction is to emphasize inquiry and assessment of students needs to be ongoing (AAAS, 1993). The implication is that the standards should be major influences on the quality science education in the United States. Specifically, NSES for life science content focus on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use (Hollweg & Hill, 1996).

Although it is implied that the NSES must be a tremendous influence on all facets of science education, the literature reviewed for this study revealed only minor evidence of the impact of these standards on biology content, instructional strategies, and assessment methods of biological science websites. In contrast, the literature provided substantial evidence indicating the influence of the NSES on instructional materials. The Instructional Materials Development (IMD) program of the National Science Foundation (NSF) signifies the influence of the NSES on instructional materials (NSF, 1994). According to the NSF (1994) and Cozzens (2000), the NSF has invested approximately 1 billion dollars in IMD projects since *A Nation at Risk* was published in 1983. Also, curriculum developers have used resources offered through the IMD program to produce several comprehensive programs for K–12 students. Consequently, numerous innovative modules have been produced in nearly every conceivable scientific domain (Cozzens, 2000; NSF, 1994).

Additional evidence indicating the influence of the NSES on instructional materials is provided by the findings of the AAAS Project 2061 Textbook Evaluations (AAAS, 2005). Reports of the AAAS (2005) revealed that many textbooks published in the past five years include a matrix of alignment of the content in the text with the NSES. This implies that textbook publishers are at least acknowledging and responding to the influence of the NSES.

Inquiry-based Instruction

Substantial research-based evidence exists to support the belief that inquiry experiences can provide valuable opportunities for learners to acquire scientific thinking skills (Glasson, 1989; Metz, 1995; White & Frederiksen, 1998). Specific indications are that inquiry experiences can help learners to improve their understanding of science content and scientific processes (Edelson, Gordin, & Pea, 1999; Glasson, 1989; Metz, 1995; White & Frederiksen, 1998). Thus, one important goal of science education reform is that scientific inquiry experiences must be brought into pK-16 classrooms (Bodzin, 2005).

There is no doubt that inquiry-based instruction combined with technology integration is a fundamental component of both NSES and the Project 2061 Benchmarks (NRC, 1996). Authors of the NSES demand that science students must be provided with opportunities to (a) explore the world; (b) identify problems; (c) think critically and pose questions; (d) formulate hypotheses; (e) design and conduct investigations; (f) collect and analyze data; (g) evaluate accuracy and identify possible sources of experimental error; (h) formulate conclusions; (i) provide possible explanations; (j) communicate findings; (k) apply scientific principles to their daily activities; and (l) make connections among scientific explorations to their personal lives and to their communities (AAAS, 1993; NRC, 1996). The implication of these mandates is that inquiry learners will develop learning strategies, such as problem solving, evidence examination, scientific reasoning, and decision-making (AAAS, 1993; NRC, 1996).

The mandates of the NSES make it clear that inquiry-based instruction requires educators to have a student-centered perspective of science teaching. Although the national standards emphasize inquiry-based instruction, great difficulties are experienced as educators attempt to facilitate inquiry-based learning (Slater et al., 2001). The reality is that many obstacles have to be eliminated in order for educators to ensure that students learn science by active inquiry rather than by memorizing facts (Edelson et al., 1999). Hence, facilitation of inquiry-based learning from a student-centered perspective is one of the outstanding challenges that contemporary educators face (Slater et al., 2001).

It is apparent that effective inquiry-based science instruction requires a wide range of learning materials (NRC, 1996). This need for a plethora of educational resources exists at a time when national, state, and local budget cuts continue to limit students' access to resources. However, educational resources for inquiry-based science instruction can be acquired if educators and students have unrestricted access to the Web's extensive array of scientific materials. Fortunately, students are gaining increased access to the World Wide Web via Internet connections (McLaughlin & Arbeider, 2008).

Based on the reviewed published literature, it is evident that the NSES with specific emphasis on inquiry should be a major influence on the design of science websites. According to Webb (1997), alignment of expectations and assessments is an important underlying principle of systemic and standards-based reform. Based on the tremendous educational importance of the Internet, the implication is that close alignment of NSES with biology content, instructional strategies as well as assessments methods on websites is a crucial underlying principle of biological science standards-based reform. Yet, no large-scale study has been done to determine the alignment of the content, instructional strategies, and assessment methods of science websites with NSES. This gap in educational research implies an urgent need for a nationally sponsored project to evaluate science websites.

Specifically, there is need for a large-scale project to evaluate biological science websites. This proposed project should be similar in many respects to the AAAS Project 2061 Textbook Evaluations. It is highly likely that findings of a large-scale evaluation of biology websites will indicate that biology content, instructional strategies, and assessment methods of only a few websites are closely aligned with the NSES for the life sciences.

Content Analysis

A review of literature on content analysis revealed gradual evolutionary trends in the description of the research paradigm. Historically, use of content analysis as a research method has been re-formulated and expanded several times (Berelson, 1952; Krippendorff, 1980; Lin & Ware, 2000). Berelson and Lazarsfeld (1948) referred to content analysis as a valid tool that can be utilized to study content of messages. In 1952, Berelson described content analysis as a systematic, objective and a quantitative method for studying communication messages. Later, Krippendorff (1980) described content analysis as a research technique that can be used for making replicable and valid inferences from data to their context.

It is apparent that the structure of any content analysis is dependent on the specific research questions that are asked (Lin & Ware, 2000). However, categorization is vital for a content analysis of the World Wide Web. According to Lin and Ware (2000), content analysis of the Web requires development of a comprehensive, mutually exclusive categorization scheme for allowing individuals to record and describe context units. These authors explicated that categorization and special approaches to content analysis are dependent on the nature of specific research questions that are to be addressed.

Content Analysis and Validity

Consensus appears to exist among researchers that content analysis is a valid research method with worldwide usage (Adam & Deans, 1999; Casty, 1973; Kinnier & Ostlund, 1997; Lin & Ware, 2000; Rosengren, 1981). Specifically, content analysis is deemed to be a valuable technique in the evaluation of websites (Philport & Arbitier, 1997). The goal of this research paradigm is to count categories and measure the amounts of other variables (Neuendorf, 2002).

According to Krippendorff (1980), validity of a content analysis is based on three important factors: stability, reliability, and reproducibility. Weber (1985) endorsed Krippendorff’s view and stated that valid content analysis has to comply with all three of these factors. Weber (1985) further explained that stability refers to invariability of results of a content analysis over the time. But, reproducibility usually refers to consistency of the results achieved, regardless of the coding methods used by the researchers. In contrast, accuracy commonly refers to extent of correspondence of the text analyzed to the established standard or norm.

Table 1 on the following page highlights the researchers, methodology, and findings of three content analyses that were reported in the reviewed literature.

Table 1

Researchers, Methodology, and Findings of Three Content Analyses

Researchers	Methodology	Findings
Lyke (2001)	The study analyzed primary student and primary teacher literacy websites using criteria based upon nationally recognized standards to determine the degrees of compliance for developmental appropriateness and literacy content appropriateness, according to nationally recognized standards. The website sample consisted of 103 primary student and primary teacher literacy websites that were systematically selected by several search engines following a definite procedure.	Significant differences existed between primary student websites and primary teacher websites in developmental appropriateness. Less than 9% of the analyzed websites were developmentally appropriate compared to 55% of websites that were literacy content appropriate in compliance with nationally recognized standards.
Kumar & Libidinsky (2000)	The study analyzed Web-based K–12 science education resources in the United States using the Science, Technology, and Society (STS) competencies developed from the NSES (NRC, 1996). The website sample for this study consisted of 51 web-based STS instructional resources collected between September and October 1998. Yahoo, Excite, Netscape, Infoseek, Lycos, Alta Vista, and Look Smart search engines were used to locate several combinations of search terms associated with the STS curriculum.	Out of the 51 resources analyzed, only 12% addressed 25% or more of the STS competencies. Twenty percent were aimed at K–12 level with 10% each at high school and middle grade levels.

(table continues)

Table 1 *(continued)*

Researchers	Methodology	Findings
Tuvi & Nachmias (2001)	95 websites teaching atomic structure were chosen between November 1999 to April 2000, using mainly Yahoo and Google search engines. The selected websites were analyzed by using a classification scheme to determine pedagogical and technological characteristics of websites.	Advanced communication means and graphical tools are rarely used on websites. The content of most analyzed websites was deemed to be reliable in their structure, level of graphics, and content. But, they resembled an online version of a textbook rather than a new, interactive, learning environment.

Chapter Summary

A synthesis of the literature related to cognitive learning theories, Internet usage, National Science Education Standards, inquiry-based instruction, and content analysis was presented in this chapter. The thorough review of published literature provided research-based evidence to support the view that websites can be effective instructional tools (Schweir & Misanchuk, 1993). Specifically, websites have the potential to increase both student motivation (Kearsley, 1996) and convenience for learning (Crossman, 1997).

Chapter 3: Method

This chapter presents the design of a content analysis that was done to determine if biology content, instructional strategies and assessment methods of a website sample are significantly aligned with the NSES for Grade 12 Life Science. One hundred biological science websites that were appropriate for Grade 12 educational purposes were analyzed by using an instrument that was developed by the researcher. The NSES for Grade 12 Life Science coupled with criteria derived from the Web-based Inquiry (WBI) for Learning Science instrument (Bodzin, 2005) and other pertinent published educational literature provided justification for items included in the instrument.

The Problem

Many students in the United States rely to a great extent on science websites for education. Yet, it is unclear if these websites are significantly aligned with National Science Education Standards (NSES). This study was done to determine whether or not the science content, instructional strategies, and assessment methods of biological science websites are significantly aligned with the NSES.

Restatement of the Hypotheses

Ho1: The content of biological science websites is not significantly aligned with National Science Education Standards.

Ho2: The instructional strategies used on biological science websites are not significantly aligned with National Science Education Standards.

Ho3: The assessment methods used on biological science websites are not significantly aligned with National Science Education Standards.

Methodology

The study employed a quantitative research design entailing use of a Web-based Inquiry (WBI) for Learning Science instrument (Bodzin, 2005) for content analysis of 100 biological science websites that were appropriate for Grade 12 biological science educational purposes.

Sample

The sample of this study consisted of 100 biological science websites that were appropriate for Grade 12 biological science educational purposes. This website sample size was determined after a power analysis was performed involving use of Soper's online a-priori sample size calculator located at http://www.danielsoper.com/statcalc/calc01.aspx. A minimum required website sample size of 76 was computed by Soper's sample size calculator based on the following parameters: (a) an alpha level of 0.05; (b) three predictors; (c) an anticipated effect size of 0.15; and (d) a desired statistical power level of 0.8.

Websites were selected in March 2009 via AltaVista, Google, Lycos, and Yahoo search engines (n = 100). The search engines searched for biological science websites that included content from at least one of the major biological science themes of Cell Structure and Function, Matter and Energy Transformations, Molecular Basis of Heredity, and Natural Selection and Evolution.

The following protocol was used for the selection of websites. Each search engine (AltaVista, Google, Lycos, or Yahoo) performed four separate searches to ensure that the website sample represented all the major biological science themes. But, Google was used first in each case.

1. Key terms for search #1 were biological science websites; activities; national science education standards; grade 12; cell structure and function.
2. Key terms for search #2 were biological science websites; activities; national science education standards; grade 12; matter and energy transformations.
3. Key terms for search #3 were biological science websites; activities; national science education standards; grade 12; molecular basis of heredity.
4. Key terms for search #4 were biological science websites; activities; national science education standards; grade 12; natural selection and evolution.

The total number of websites obtained by each search was recorded. But, the sample consisted of no more than the first 30 sites revealed by each search that referred to all the search terms and were not previously selected.

Procedure

Instrumentation

The data collection instrument for use in this study was custom developed by the researcher using criteria based on the Web-based Inquiry for Learning Science instrument (Bodzin, 2005) and other pertinent information garnered from literature that was discussed in Chapter 2 (see Appendix A). This instrument asks 21 questions that are categorized into three distinct areas:

1. Biology content

2. Instructional strategies

3. Assessment methods

Criteria for analyzing biology content include four questions:

1. Are goals, objectives, or desired learning outcomes carefully defined (Bruner, 1977; Gagne, 1987)?

2. Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science (Moore & Huber, 2001; NRC, 1990)?

3. Is the content appropriately sequenced to foster acquisition of fundamental biological science knowledge that emphasizes major scientific ideas which will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?

4. Does the content include historical case studies that relate to some of the basic scientific ideas (Bybee, 2002)?

Criteria for analyzing instructional strategies include 13 questions:

1. Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate (Olson & Loucks-Horsley, 2000)?

2. Do instructional strategies foster a constructivist approach to learning (Bednar et al., 1992; Gordon, 2008; Marlowe & Page, 2005; Shuell, 1986; Tobin, Capie, & Bettencourt, 1988; Windschitl, 2002)?

3. Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues (Clark & Gorski, 2001)?

4. Do instructional strategies promote real-world problem solving and/or applications (Bybee, 2002; Raizen, 1998)?

5. Are learners engaged by scientifically oriented questions (Bodzin, 2005; NRC, 2000)?

6. Are learners prompted to formulate their own questions or hypotheses that can be tested (Bodzin, 2005; NRC, 2000)?

7. Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations (Olson & Loucks-Horsley, 2000)?

8. Are learners encouraged to use evidence for drawing conclusions (Bodzin, 2005; NRC, 2000)?

9. Are learners encouraged to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?

10. Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations (Olson & Loucks-Horsley, 2000)?

11. Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics (Olson & Loucks-Horsley, 2000)?

12. Are illustrative examples provided for allowing learners to construct new knowledge that facilitates understanding of facts and/or ideas in the context of a conceptual framework (Bruner, 1977; Bybee, 2002; Gagne, 1987)?

13. Is emphasis placed on allowing students to apply and extend science learning to their daily lives (Pratt, 1998)?

Criteria for analyzing assessment methods include four questions:

1. Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002; Linn & Hsi, 2000)?
2. Are opportunities provided for learners to communicate and justify their proposed explanations of events (Bodzin, 2005; NRC, 2000)?
3. Are learners required to use evidence for drawing and reporting conclusions (Bodzin, 2005; NRC, 2000)?
4. Are learners required to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?

The data collection instrument employed in the pilot study was custom developed by the researcher using criteria based on the Web-based Inquiry for Learning Science instrument (Bodzin, 2005) and other pertinent information garnered from literature that was discussed in Chapter 2. Unlike the 21-item instrument employed in the main study, the one used in the pilot study asks 22 questions. Both instruments ask questions related to three distinct areas: (a) biology content; (b) instructional strategies; and (c) assessment methods.

The instrument used in the main study actually burgeoned from the pilot study instrument. Specifically, the instruments differed in four ways with the instrumentation for the main study being a refined version of the pilot study instrument. All the instrument modifications were based on the interrater Pearson correlation output that was generated by SPSS. In three out of four cases, the rationale for modification of the pilot instrumentation was justified by pertinent data.

Item # 1 of the pilot instrument was not included in the refined instrument because at least one of the variables in the raw data was constant and SPSS could not compute the Pearson correlation. The item asks the question, “Does the content refer to a topic stipulated by the NSES for Grades 9-12 Life Science: The cell; Molecular basis of heredity; Biological evolution; Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms (NRC, 1996)?” Although SPSS could not compute the Pearson correlation for item # 4 interrater data, the item was reworded and incorporated into the refined instrument. The question asked by the item was changed from “Is the content appropriately sequenced to foster acquisition of fundamental biological science knowledge that emphasizes major scientific ideas which will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?” to “Does the content foster acquisition of fundamental biological science knowledge that emphasizes major scientific ideas which will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?”

Item #7 of the pilot instrument was modified to include a definition of active learning. Hence, the question asked by the item was changed from “Do instructional strategies promote active learning (Bednar et al., 1992; Shuell, 1986; Tobin et al., 1988)?” to “Do instructional strategies foster a constructivist approach to learning (Bednar et al., 1992; Gordon, 2008; Marlowe & Page, 2005; Shuell, 1986; Tobin et al., 1988; Windschitl, 2002)?” Like item # 4 of the pilot instrument, item # 7 was reworded and included in the refined instrument. The decision to reword both items 4 and 7 was initiated by the SPSS notation that at least one of the variables in the raw data was constant and SPSS could not compute the Pearson correlation. The question included in item # 17 was changed from “Do instructional strategies facilitate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002)?” to “Are illustrative examples provided for allowing learners to construct new knowledge that facilitates understanding of facts and/or ideas in the context of a conceptual framework (Bruner, 1977; Bybee, 2002; Gagne, 1987)?”

Data for each analyzed website were recorded on a separate data collection sheet. A “Y” was recorded in the designated space on each sheet to denote a “yes” response to the question asked by each item in the data collection instrument. In contrast, “N” was recorded to denote a “no” response to each question. For this research, “yes” responses to 3 out of 4 questions in the biology content category indicated acceptable alignment of the website’s biology content with instrument-based indicators of alignment with the NSES that relate to biology content. “Yes” responses to 11 out of 13 questions in the instructional strategies category indicated acceptable alignment of the website’s instructional strategies with indicators of alignment with the NSES that relate to instructional strategies. “Yes” responses to 3out of 4 questions in the assessment methods category indicated acceptable alignment of the website’s assessment methods to the NSES that relate to assessment methods. Overall, “yes” responses to 17 out of 21 questions included in the data collection instrument indicated an acceptable 85% alignment of a website’s biological science content, instructional strategies, and assessment methods with the NSES. “Yes” responses for each analyzed website are shown in Appendix D.

Instrument validity. Efforts were made to ensure that the data collection instrument had high construct validity. Hence, the NSES, relevant published literature, and the Web-based Inquiry for Learning Science instrument developed by Bodzin and Cates (2003) provided a framework for the development of the instrument that was used in this study. Each draft of the instrument was modified based on the critiques of three university science professors and three expert biology college professors.

Instrument reliability. Great efforts were made to ensure that the data collection instrument had a high level of reliability. Thus, a pilot study was done in which two trained raters/biological science educators pre-tested the instrument. Specifically, each trained rater used the instrument for content analysis of 20 selected biological science websites designed for educational purposes. Websites that are analyzed in the pilot study were not included in the final research.

Training of raters involved several important stages. In the first stage, the raters discussed and interpreted each item included in the data collection instrument. The second stage required raters to use the instrument independently for analyzing two biological science websites. In the third stage, raters compared the results of the data collection process and came to a consensus about specific use of the instrument. The second and third stages of the training process were repeated until there was at least 95% similarity in results obtained by the raters.

Determination of instrument reliability. Instrument reliability was determined based on findings of the pilot study involving the two trained independent raters/biological science educators. During the pilot study, the raters/biological science educators independently analyzed and manually coded the content of 20% (n=20) of the total number of selected websites that were investigated during the entire research (n=100). Subsequently, interrater reliability was established by Pearson's correlation of the mean tallied itemized data, Pearson's correlation of the mean categorized data, and comparison of χ^2 computations of the two independent raters. The pilot Microsoft Excel and the Statistical Package for the Social Sciences (SPSS) software programs were used to perform interrater reliability analyses. The pilot study report is shown in Appendix B.

Pearson's correlation for overall instrument reliability was 0.885. Interrater χ^2 values were significant ($p < 0.05$) for 90% of the items included in the data collection instrument. Specifically, the findings of the pilot study indicated that the interrater correlations for 18 out of 22 items included in the instrument were statistically significant at the < 0.05 level (2-tailed).

It is important to note that SPSS was unable to compute interrater correlation values for items 1, 4, and 17 (3 out of 22 items) included in the instrument because at least one of the variables was constant. However, with the exception of the correlation value for item 14 that was not significant at the acceptable 0.05 level, all the 19 computed correlation values were significant at the < 0.05 level (2-tailed). The overall χ^2 values for each category were significant at the < 0.05 level (2-tailed). In addition, 17 out of 20 websites were significant at the 0.05 level (2-tailed). These results indicate that 4 of the 22 items included in the data collection instrument lacked a high level of reliability and construct validity. This implies that these items were not appropriate for use during content analysis of biological science websites. Thus, a decision was made to delete item #1 from the instrument and to modify items 4, 14, and 17 in order to make their meaning more explicit.

Variables

Independent Variables

The independent variables of this study are the selected biological sciences websites.

Dependent Variables

The dependent variables of the study are the frequencies of occurrence of alignment of biology content, instructional strategies, and assessment methods of the analyzed websites with indicators of alignment with the NSES included in the data collection instrument.

Data Collection

Content analysis of each selected website was done between March and November 2009. The pilot analysis of 20 websites was done independently in March and April 2009 by two trained raters/biological science educators. Both raters used the researcher’s custom developed instrument for website analysis and data collection.

Alignment of biology content, instructional strategies as well as assessment techniques of each website with criteria included in the data collection instrument was indicated by “yes” responses to questions included in the data collection instrument. In contrast, no alignment of biology content, instructional strategies, and assessment techniques of each website with criteria included in the data collection instrument was indicated by “no” responses to questions included in the data collection instrument. Frequencies of “yes” responses indicating alignment and “no” responses indicating no alignment of biology content, instructional strategies, and the assessment techniques of each website with criteria included in the data collection instrument were tabulated.

The researcher performed the main study between October and November 2009 by conducting a content analysis of 80 preselected websites. This analysis employed a refined version of the data collection instrument that was utilized in the pilot study. The total number of “yes” responses computed for each website in the main study was deemed to be indicative of the overall alignment of the website attributes with the NSES. Hence, the frequencies of “yes” responses generated in the main study were used to rank 80 analyzed websites in terms of their overall alignment with the NSES.

Data Analysis

Microsoft Excel and a SPSS software program were used for statistical analysis in this study. 20% (n=20) of the selected websites were analyzed in the pilot study and 80% (n=80) were analyzed in the main study. The websites analyzed in the pilot study are listed in Appendix B and those analyzed in the main study are listed in Appendix C. χ^2 tests were performed to determine whether or not the actual frequencies of alignment of biology content, instructional strategies as well as assessment methods of the analyzed websites with website indicators of alignment with the NSES differ significantly from an expected 85% alignment with the standards.

The decision to perform χ^2 tests using 85% expected alignment of website indicators with the NSES was based on the non-parametric nature of the data and the premise that an expected 100% alignment of website indicators with the NSES was highly improbable. Based on the coin flip probability model, it is reasonable to expect 50% of the attributes of the analyzed websites to be significantly aligned with the NSES. However, a definite decision was made not to base acceptable alignment for this research on a coin flip probability model because of the notion that it was unacceptable for only

50% of the content, instructional strategies and assessment methods of biological science websites to be aligned with the NSES. Alternatively, an 85% rule of acceptable alignment for each website indicator of alignment with the NSES was subjectively established by the researcher.

A χ^2 test was performed to determine the overall significant difference of data alignment with an expected 85% alignment with the NSES. Additional χ^2 tests were performed to determine the significant difference of data alignment for each analyzed item and for each of the 3 analyzed categories with an expected 85% alignment with the NSES. The level of significance for each χ^2 test was set at 0.05.

Chapter 4: Results

This chapter presents results of statistical tests of hypotheses that are restated below. A χ^2 test was performed to determine the overall significant difference of data alignment with an expected 85% alignment with the NSES. Other χ^2 tests were done to determine the significant difference of data alignment for each analyzed item with an expected 85% alignment with the NSES. Additional χ^2 tests were carried out to determine the significant difference of data alignment for each of the 3 analyzed categories with an expected 85% alignment with the NSES. The level of significance for each χ^2 test was set at 0.05.

Restatement of the Hypotheses

Ho1: The content of biological science websites is not significantly aligned with National Science Education Standards.

Ho2: The instructional strategies used on biological science websites are not significantly aligned with National Science Education Standards.

Ho3: The assessment methods used on biological science websites are not significantly aligned with National Science Education Standards.

Microsoft Excel software was used to perform χ^2 significance tests of each hypothesis stated above at a significance level of 0.05. The χ^2tests were specifically performed to determine differences in actual and expected 85% frequencies of alignment of biological science website content, instructional strategies and assessment methods with indicators of alignment to NSES.

A χ^2 probability test of Ho1 revealed significant non-alignment of content data with indicators of the NSES ($p < 0.05$). Specifically, 3 out of 4 attributes in the content category of the analyzed websites were less well aligned than 85% with the NSES. Hence, Ho1: “The content of biological science websites is not significantly aligned with National Science Education Standards” was accepted. A χ^2 probability test of Ho2 indicated significant non-alignment of data related to instructional strategies with indicators of the NSES ($p < 0.05$). All 13 attributes in the instructional strategies category of the analyzed websites were less well aligned than 85% with the NSES. Thus, Ho2: “The instructional strategies used on biological science websites are not significantly aligned with National Science Education Standards” was accepted. The χ^2 probability test of Ho3 revealed significant non-alignment of data related to assessment methods with indicators of the NSES ($p < 0.05$). All 4 attributes in the assessment methods category of the analyzed websites were less well aligned than 85% with the NSES. Therefore, Ho3: “The assessment methods used on biological science websites are not significantly aligned with National Science Education Standards” was accepted. The acceptance of all three hypotheses indicates significant difference in the alignment of the analyzed website content, instructional strategies, and assessment methods with an expected 85% alignment to the NSES.

Categorical and overall χ^2 results for biological science website content, instructional strategies, and assessment methods as well as the relevant percentage yes and no responses are shown in Table 2. The χ^2 tests were performed to determine significant differences in actual and expected 85% frequencies of data alignment with indicators of alignment to NSES.

Table 2

Categorical and Overall Percentage Yes/No Responses and χ^2 Results for Indicators of Website Alignment with the NSES

Item Category	% Yes Responses	% No Responses	χ^2 Values based on yes/no responses	df	*p* Values
Biology content	69.38	30.63	61.27	1	0.001*
Instructional strategies	44.52	55.48	1336.66	1	0.001*
Assessment methods	25.31	74.69	894.14	1	0.001*
Overall	45.60	54.40	2045.96	1	0.001*

Note. * $p < 0.05$ (2-tailed) *The minimum acceptable "yes" response is 85%*

In Table 2, the 69.38 % "yes" response was computed by expressing 222 (the observed number of "yes" biology content responses) as a percentage of 320 (the total possible number of content "yes" responses). The 44.52 % yes response was computed by expressing 463 (the observed number of instructional strategies "yes" responses) as a percentage of 1040 (the total possible number of number of instructional strategies "yes" responses). The 25.31 % "yes" response was computed by expressing 81(the observed number of assessment methods "yes" responses) as a percentage of 320 (the total possible number of "yes" assessment methods responses). The overall % "yes" response of 45.60 shown in Table 2 was obtained because 766 (the sum of observed responses for content, instructional strategies, and assessment methods) was expressed as a percentage of 1680, which represents the total possible “yes” responses that could be obtained. The %“no” responses for each category shown in Table 2 were computed by subtracting each % “yes” response from 100.

In Table 2, data for all the analyzed categories showed a significant difference of alignment with the indicators. Specifically, all the % “yes” responses were less than the threshold 85%. So, the results of the χ^2 tests shown in Table 2 indicate significant non-alignment of each analyzed category with the NSES. For content, $\chi^2 = 61.27$, df = 1, $p < 0.05$. For instructional strategies, $\chi^2 = 1336.66$, df = 1, $p < 0.05$. For assessment methods, $\chi^2 = 894.14$, df = 1, $p < 0.05$. The overall data for the combined analyzed categories also showed a significant difference of alignment with indicators. ($\chi^2 = 2045.96$, df = 1, $p < 0.05$). χ^2 values and the number of “yes” and “no” responses to each question in the content category of the data collection instrument are presented in Table 3.

Table 3

χ^2 Results and the Number of Yes/No Responses for

Indicators of Alignment of Website Content with the NSES

Indicators	Yes Responses	No Responses	χ^2 Values	df	*p* Values
1. Are goals, objectives, or desired learning outcomes carefully defined?	33	47	120.10	1	0.001*
2. Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science?	67	13	0.10	1	0.75
3. Is the content appropriately sequenced to foster acquisition of fundamental biological science knowledge that will contribute to development of a strong conceptual framework in students?	80	0	14.12	1	0.001*
4. Does the content include historical case studies that relate to some of the basic scientific ideas?	42	38	66.27	1	0.001*

Note. * $p < 0.05$ (2-tailed) *The minimum acceptable # of "yes" responses is 68 (85%)*

In Table 3, data obtained for items 1and 4 showed significant difference of non-alignment with indicators of the NSES ($p < 0.05$). With reference to item #1 only 33 of 80 websites are in alignment with the NSES. So, most of the analyzed websites are not in alignment with the mandate for goals, objectives, or desired learning outcomes to be carefully defined. The “yes” response to item #4 indicates that only 42 of 80 websites are in alignment with the NSES. Therefore, 47.5% of the analyzed websites are not in alignment with the mandate for inclusion of historical case studies that relate to some of the basic scientific ideas.

The “yes” response to item #3 shown in Table 3 indicates that all 80 of the analyzed websites are significantly aligned with the NSES mandate for inclusion of content that is appropriately sequenced to foster acquisition of fundamental biological science knowledge. Unlike the other items for analysis of website content that were included in Table 2, item #2: “Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science?” yielded data that showed no significant difference in alignment with indicators of the NSES ($\chi^2 = 0.10$, df = 1, $p > 0.05$). However, the “yes” response for item #2 indicates that 83.75% of analyzed websites are aligned the NSES. The *p* value of 0.75 for this item indicated no significant difference in alignment because it was below the expected 85% threshold value. So, Table 3 showed that data for 3 out of the 4 items in the content category had significant difference of alignment with indicators of alignment to the NSES ($p < 0.05$). However, only item #3 was significantly aligned with the NSES. Items 1 and 4 were significantly non-aligned and had less than 85% alignment with the NSES. Item 2 generated data that was not significantly different from the expected 85% acceptable level of alignment with the NSES.

In Table 3, item #1: “Are goals, objectives, or desired learning outcomes carefully defined?” showed a significant difference in alignment with indicators of the NSES (χ^2 =

120.10, df = 1, $p < 0.05$). This item generated a “yes” response of 41.25%. So, the data were significantly non-aligned with the related indicator of the NSES. Data obtained for item #2: “Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science?” showed no significant difference in alignment with indicators of the NSES ($\chi^2 = 0.10$, df = 1, $p > 0.05$). The “yes” response for item #2 indicates that 83.75% of analyzed websites are aligned the NSES. This alignment was slightly below the expected 85% acceptable level for alignment with the NSES. Data for item #3: “Is the content appropriately sequenced to foster acquisition of fundamental biological science knowledge that will contribute to development of a strong conceptual framework in students?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 14.12$, df = 1, $p < 0.05$). All 80 websites (100%) were in compliance with this indicator of alignment. So, the data generated by this item were significantly aligned with the related indicator of the NSES. Data for item #4: “Does the content include historical case studies that relate to some of the basic scientific ideas?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 66.27$, df = 1, $p < 0.05$). The “yes” response for this item indicates that 52.5% of analyzed websites are aligned the NSES. However, the data generated by the item were significantly non-aligned with the relevant indicator of the NSES. χ^2 values and the number of “yes” and “no” responses to each question in the instructional strategies category of the data collection instrument are presented in Table 4.

Table 4

Number of Yes/No Responses and χ^2 Results for Indicators of Alignment of Website Instructional Strategies with the NSES

Indicators	Yes responses	No Responses	χ^2 Values	df	*p* Values
1. Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate?	50	30	31.76	1	0.001*
2. Do instructional strategies foster a constructivist approach to learning?	55	25	16.57	1	0.001*
3. Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues?	43	37	61.27	1	0.001*
4. Do instructional strategies promote real-world problem solving and/or applications?	46	34	50.86	1	0.001*
5. Are learners engaged by scientifically oriented questions?	50	30	31.76	1	0.001*
6. Are learners prompted to formulate their own questions or hypotheses that can be tested?	11	69	318.53	1	0.001*

(table continues)

Table 4 *(continued)*

Indicators	Yes responses	No Responses	χ^2 Values	df	*p* Values
7. Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations?	18	62	245.10	1	0.001*
8. Are learners encouraged to use evidence for drawing conclusions?	24	56	189.80	1	0.001*
9. Are learners encouraged to evaluate their conclusions in light of alternative conclusions?	9	71	341.27	1	0.001*
10. Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations?	24	56	189.80	1	0.001*
11. Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics?	13	67	296.57	1	0.001*
12. Are illustrative examples provided to enhance understanding of facts and/or ideas in the context of a conceptual framework?	76	4	6.27	1	0.01*
13. Is emphasis placed on allowing students to apply and extend science learning to their daily lives?	44	36	56.47	1	0.001*

Note. * $p < 0.05$ (2-tailed) *The minimum acceptable # of "yes" responses is 68 (85%)*

Data obtained for all items in Table 4 showed a significant difference of alignment with indicators of alignment to NSES. However, the data generated by all items except item #12 were significantly non-aligned with the related indicators of alignment with the NSES. The “yes” response for this item indicates that 95% of analyzed websites are significantly aligned with the mandate for provision of illustrative examples that enhance understanding of facts and/or ideas in the context of a conceptual framework.

Data for item #1: “Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 31.76$, df = 1, $p < 0.05$). For item #1, 50 out of 80 “yes” responses were generated by this item. So, 62.5% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. The data obtained for item #2: “Do instructional strategies foster a constructivist approach to learning?” revealed a significant difference in alignment with indicators of the NSES ($\chi^2 = 16.57$, df = 1, $p < 0.05$). Item #2 generated 55 out of 80 “yes” responses. So, 68.75% of the analyzed websites were significantly non-aligned with the related indicator of the NSES for this item. Item #3: “Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues?” yielded data that showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 61.27$, df = 1, $p < 0.05$). This item generated 43 out of 80 “yes” responses. Hence, 53.75% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. Item #4: “Do instructional strategies promote real-world problem solving and/or applications?” resulted in data that showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 50.86$, df = 1, $p < 0.05$). This item generated 46 out of 80 “yes” responses. So, 57.5% of the analyzed websites were significantly non-aligned with the related indicator of the NSES.

Data for item #5 “Are learners engaged by scientifically oriented questions?” indicated a significant difference in alignment with indicators of the NSES ($\chi^2 = 31.76$, df = 1, $p < 0.05$. Like item # 1 in this category, item #5 generated 50 out of 80 “yes” responses. Therefore, 62.5% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. Item #6: “Are learners prompted to formulate their own questions or hypotheses that can be tested?” yielded data that showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 318.53$, df = 1, $p < 0.05$). Only 11 out of 80 “yes” responses were generated by this item. So, 13.75% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. This result is far below the acceptable expected 85%. Data obtained for item #7: “Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 245.10$; df = 1; $p < 0.05$). Only 18 out of 80 “yes” responses were generated by this item. So, 22.5% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. This result is also far below the acceptable expected 85%.

Data for item #8: “Are learners encouraged to use evidence for drawing conclusions?” also showed a significant difference in alignment with indicators of the NSES ($\chi^2= 189.80$, df = 1, $p < 0.05$). Only 24 out of 80 “yes” responses were generated by this item. So, 30% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. Item #9: “Are learners encouraged to evaluate their conclusions in light of alternative conclusions?” yielded data that revealed a significant difference in alignment with indicators of the NSES ($\chi^2 = 341.27$, df = 1, $p < 0.05$). Only 9 out of 80 “yes” responses were generated by this item. So, 11.25% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. This result is extremely far below the acceptable expected 85%. Data for item #10: “Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 189.80$, df = 1, $p < 0.05$). Like item #8 in the instructional strategies category, 24 out of 80 “yes” responses were generated by this item. So, 30% of the analyzed websites were significantly non-aligned with the related indicator of the NSES.

Data obtained for item #11: “Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 296.57$, df = 1, $p < 0.05$). Only 13 out of 80 “yes” responses were generated by this item. So, 16.25% of the analyzed websites were significantly non-aligned with the related indicator of the NSES. This result is also extremely far below the acceptable expected 85%. Data for item #12: “Are illustrative examples provided to enhance understanding of facts and/or ideas in the context of a conceptual framework?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 6.27$, df = 1, $p < 0.05$). This is the only item in this category that generated data that were significantly aligned with the related indicator of the NSES.

In addition, data obtained for item #13 “Is emphasis placed on allowing students to apply and extend science learning to their daily lives?” showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 56.47$, df = 1, $p < 0.05$).

χ^2 values and the number of “yes” and “no” responses to each question in the assessment methods category of the data collection instrument are presented in Table 5.

Table 5

Number of Yes/No Responses and χ^2 Results for Indicators of Alignment of Website Assessment with the NSES

Indicators	Yes Responses	No Responses	χ^2 Values	df	*p* Values
1. Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002; Linn & Hsi, 2000)?	45	35	51.86	1	0.001*
2. Are opportunities provided for learners to communicate and justify their proposed explanations of events (Bodzin, 2005; NRC, 2000)?	16	64	265.10	1	0.001*
3. Are learners required to use evidence for drawing and reporting conclusions (Bodzin, 2005; NRC, 2000)?	14	66	285.88	1	0.001*
4. Are learners required to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?	6	74	376.86	1	0.001*

Note. * $p < 0.05$ (2-tailed) *The minimum acceptable # of yes responses is 68 (85%)*

In Table 5, data for all items showed a significant difference of alignment with indicators of alignment with NSES. However, all the items in this category generated data that were significantly non-aligned with the NSES. Data obtained for item #1: “Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework?" showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 51.86$, df = 1, $p < 0.05$). This item generated a "yes" response of 56.25%. So, the data were significantly non-aligned with the relevant indicator of the NSES. Data obtained for item #2: "Are opportunities provided for learners to communicate and justify their proposed explanations of events?" showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 265.10$, df = 1, < 0.05). The item generated a "yes" response of only 20%. This result is far below the acceptable expected 85%. Hence, the data were significantly non-aligned with the relevant indicator of the NSES. Data obtained for item #3: "Are learners required to use evidence for drawing and reporting conclusions?" showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 285.88$, df = 1, $p < 0.05$). This item generated a "yes" response of only 17.5%. This result is also far below the acceptable expected 85%. Therefore, the data were significantly non-aligned with the relevant indicator of the NSES. Data for item #4: "Are learners required to evaluate their conclusions in light of alternative conclusions?" showed a significant difference in alignment with indicators of the NSES ($\chi^2 = 376.86$, df = 1, $p < 0.05$). The item generated a "yes" response of only 7.5%. This result is also extremely far below the acceptable expected 85%. So, the data were significantly non-aligned with the relevant indicator of the NSES.

The overall results obtained when Microsoft Excel software performed χ^2 tests to determine the significant difference of data alignment between the actual and expected 85% alignment with the standards for each website are shown in Appendix D. Fourteen out of eighty (17.5%) of analyzed websites yielded data that were not significantly aligned with indicators of alignment with the NSES. Hence, a significant difference of ($p < 0.05$) was obtained between the overall actual and expected frequencies of alignment of biology content, instructional strategies, and assessment methods for 82.5% of analyzed websites with indicators of alignment with the NSES. It is important to note that only 11 out of 80 analyzed websites had at least 85% of their attributes in alignment with the NSES. Hence, 86.25% of the analyzed websites had less than the threshold 85% alignment with the NSES.

Ranking of the analyzed websites based on the frequencies of "yes" responses generated in the main study indicated that the *Cell and Molecular Biology Online* website (# 24) located at *http://www.cellbio.com/education.html* was most strongly aligned with the NSES in terms of content, instructional strategies, and assessment methods. In contrast, the *Virtual Cell Animation Collection* website (# 72) located at *http://vcell.ndsu.nodak.edu/animations/etc/movie.htm* and the *Photosynthesis* website (# 76) located at *http://biology.clc.uc.edu/courses/bio104/photosyn.htm* were most weakly aligned with the NSES in terms of content, instructional strategies, and assessment methods. The rank of each website analyzed in the main study is shown in Appendix D.

Chapter Summary

This chapter presents results of χ^2 tests that were performed to determine the significant difference of data alignment between the actual and expected 85% alignment with indicators of website content, instructional strategies, and assessment methods alignment with the NSES. The level of significance for each χ^2 test was set at 0.05. These results indicated that 3 out of 4 of the analyzed content attributes, 12 out of 13 of the instructional strategies, and all the assessment methods of the researched biological science websites were less than 85% aligned with the NSES. Appropriately sequenced content that fostered acquisition of fundamental biology knowledge was the only content attribute with significantly more than 85% alignment with the NSES. Provision of illustrative examples to enhance understanding of facts and/or ideas in the context of a conceptual framework was the only instructional strategies attribute that was significantly more than 85% aligned with the NSES. The chapter also presents the analyzed websites that were found to be most strongly and most weakly aligned with the NSES based on their biological science content, instructional strategies, and assessment methods.

Chapter 5: Discussion

Restatement of the Scope of the Study

This study analyzed the biology content, instructional strategies, and assessment methods of a sample of biological science websites that were designed for Grade 12 educational purposes. The analysis determined if biology content, instructional strategies, and assessment methods of the website sample are significantly aligned with the NSES for Grade 12 Life Science. An overall sample of 100 biological science websites that were appropriate for Grade 12 biological science education was analyzed. Of the total number of websites, 20 were analyzed during a pilot study in order to establish the reliability of the data collection instrument.

Discussion of Findings

The findings of this study indicate that at a 0.05 level of significance, there is an overall difference between the actual and expected frequencies of alignment of biology content, instructional strategies, and assessment methods with the indicators. In addition, the findings indicate that there is a significant difference between the actual and expected 85% frequencies of alignment of analyzed categories (biology content, instructional strategies, and assessment methods) of the sampled websites with website indicators ($p < 0.05$). One specific finding of this study is that the content, instructional strategies, and assessment methods of 82.5 % of the analyzed biology websites are significantly non-aligned with the NSES.

The *p* values shown in Table 2 indicate significant difference in alignment of the data with the NSES. However, all the percentage “yes” responses in Table 2 for the analyzed categories are significantly lower than the expected 85% acceptable alignment of website biology content, instructional strategies, and assessment methods with the NSES. So, the data shown in Table 2 are indicative of significant non-alignment of the biology content, instructional strategies, and assessment methods of the analyzed websites with the NSES.

With specific reference to the biology content of the selected websites, the % “yes” response shown in Table 2 is only 69.38. This value is significantly lower than the expected 85% acceptable alignment of website biology content with the NSES. Hence, the website content data provide support for accepting Ho1: The content of biological science websites is not significantly aligned with National Science Education Standards.

The % “yes” response shown in Table 2 for website instructional strategies is only 44.52. This value is significantly lower than the expected 85% acceptable alignment of website instructional strategies with the NSES. Thus, the instructional strategies data provide support for accepting Ho2: The instructional strategies used on biological science websites are not significantly aligned with National Science Education Standards.

In Table 2, the % “yes” response shown for assessment methods is only 25.31. This value is significantly lower than the expected 85% acceptable alignment of website assessment methods with the NSES. Therefore, the website assessment methods data provide support for accepting Ho3: The assessment methods used on biological science websites are not significantly aligned with National Science Education Standards.

Findings of this study provided support for accepting Ho1 and concluding that the content of biological science websites is significantly non-aligned with the NSES. Findings of the study also provided support for accepting Ho2 and concluding that the instructional strategies used on biological science websites are significantly non-aligned with the NSES. Additional findings of the study provided support for accepting Ho3 and concluding that the assessment methods of biological science websites are significantly non-aligned with NSES.

The major finding of this study is that there is significant non-alignment of the biology content, instructional strategies, and assessment methods of the analyzed websites with the NSES. However, a website such as the *Cell and Molecular Biology Online* website located at *http://www.cellbio.com/education.html* includes content, instructional strategies, and assessment methods that are significantly aligned with the NSES. This website was compliant with all criteria that were included in the data collection instrument. Hence, it was ranked above all the other analyzed websites in this study. The attributes of this website contrast sharply with the *Virtual Cell Animation Collection* website located at *http://vcell.ndsu.nodak.edu/animations/etc/movie.htm*. Specifically, the *Virtual Cell Animation Collection* website was compliant with only two criteria of the data collection instrument.

The specific implication of this finding is that websites which comply with at least 85% of the NSES have several exemplary features. It is highly likely that these websites will emphasize a broad view of science content, student-centered instruction, a wide range of assessment procedures, student thinking, application of science knowledge and understanding, and learning for career awareness as well as exploration. These websites are powerful science educational resources with the potential to foster science education reform.

This research revealed that the analyzed biological science websites, which were significantly aligned with the NSES, had sharply contrasting attributes to those of websites that were not significantly aligned with the standards. One important implication of this finding is that science websites, which are not in compliance with the NSES, may hinder rather than enhance the science educational process. So, it is unfortunate that the major finding of this study is that the content, instructional strategies, and assessment methods of the analyzed websites are significantly non-aligned with the NSES. Most of the analyzed websites had less than 85% of their attributes in alignment with the NSES.

The fact that the content, instructional strategies, and assessment methods of the analyzed biological science websites are significantly non-aligned with the NSES is unsatisfactory and supports the consensus among educators that the content of educational websites needs to be regulated (Leonard, 2001; Mashhadi & Han, 1996; Wilkinson et al., 2003). This finding implies that Web resource-based learners need knowledge of how to quickly and accurately evaluate the attributes of websites that they utilize. The finding also implies that it is the role of teachers, coaches, or some other able educator to ensure that students know how to select and utilize websites that have many attributes aligned with the NSES.

It is important to realize that the NSES were developed in response to awareness among members of the National Science Teachers Association, the American Association for the Advancement of Science (AAAS), and the National Research Council (NRC) that National Science Education Standards are necessary for reforming science education in the United States (AAAS, 1993; NRC, 1996). It is also important to realize that alignment of the content, instructional strategies and assessment methods of biological science websites with the NSES is a major facet of the science educational reform process. Thus, educators need to be aware that biological websites with attributes aligned with the NSES have the potential to promote equitable, student-centered, web-based science education.

According to Webb (1997), alignment of expectations and assessments is an important underlying principle of systemic and standards-based reform. A reasonable assumption is that aligned goals and measures of attainment of these goals will increase the likelihood that educators across the nation will be working towards common goals. This implies that alignment of NSES with biological science content, instructional strategies, and assessments methods on websites is a crucial underlying principle of biology standards-based reform.

Inherent in the standards is the notion of excellence in science education for all students. This notion implies that all students irrespective of their age, sex, culture, ethnicity, disabilities, or other differences should have access to web-based resources and equivalent learning opportunities to achieve scientific literacy. A specific implication of the notion is that science website designers need to implement inclusion policies that foster equitable web-based science education for all students. The onus is on teachers and other website designers to comply with the NSES in order to fulfill mandates that foster inclusive biological science education.

Implications

Overall, the findings of this study have several implications for science education reform. For example, the fundamental findings of the study have the potential to enhance biology teaching and foster biology learning. From the perspective of incorporating technology in science education, findings of the study can stimulate development of biological science websites, initiate improvement of website designs, promote web-assisted education, and foster scientific literacy.

It is important to realize that the findings of this study are not only applicable to biological science education. On a larger scale, findings of the study can be applied to other disciplines such as chemistry, physics, and environmental science. Specific findings can guide curriculum development, enhance professional development programs, and facilitate inclusion of diverse groups of science students in high schools and colleges.

Biology Teaching

Findings of this study have added to the extant body of knowledge about the educational value of websites. One specific implication of these findings is that the analyzed websites can be used to improve biological science teaching in high schools and possibly in colleges. Another implication is that the analyzed websites can be used to improve curriculum development and professional development programs for teachers in high schools and colleges.

An important implication of the findings of this study is that the analyzed websites have the potential to provide teachers with optional instructional strategies for implementing the mandates that are specified by the NSES. An additional implication of the findings is that the instructional strategies are justified by cognitive learning theories. Hence, biology teaching that incorporates the instructional offerings of the analyzed websites has the potential to support active, constructive, goal-oriented learning. This type of teaching has the potential to foster meaningful learning and improve the academic achievement of biology students.

Some websites that were analyzed in this study displayed instructional strategies that are deemed to be cognitively important. These strategies foster a constructivist approach to learning; promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues; and promote real-world problem solving and/or applications. These website attributes are deemed to foster meaningful learning in contrast to rote memorization. It is commendable that as many as 68.75% (55 out of 80) of the analyzed websites in the main study included instructional strategies for fostering a constructivist approach to learning. It is encouraging to know that 53.75% (43 out of 80) and 57.5% (46 out of 80) of the analyzed websites in the main study employed instructional strategies for respectively promoting the development of higher-order thinking skills and real-world problem solving and/or applications.

Science websites that employ instructional strategies, which are based on cognitive learning theories such as Anchored Instruction and Situated Learning theories, provide learners with valuable educational tools. These websites expose students to interactive video technology and other technology-based tools that promote meaningful problem-based learning. Instructional models that promote the development of higher-order thinking and problem-solving are important for helping learners to achieve important science education as well as professional goals.

In *Approaches to Interactive Video Anchors in Problem-based Science Learning*, Kumar (2010) declared that one of the aims of science education is to prepare students for life through the cultivation of cognitive skills needed to solve real-world problems. Science students who are skilled critical thinkers and problem-solvers tend to engage actively in meaningful learning that improves learning outcomes. Unlike individuals who merely learn by rote memorization, students who engage in meaningful learning are usually high achievers who are able to use knowledge appropriately in novel circumstances.

Specific findings of this study indicate that some of the analyzed websites allow students to apply and extend science learning to their daily lives; promote development of abilities and/or understanding of how to use technology and/or mathematics as well as promote real-world problem solving and/or applications. Such findings imply that websites with these types of attributes can be used for teaching science, technology, and society (STS) aspects of biological science courses.

It is important to note that only 16% (13 out of 80) of the analyzed websites in the main study employed instructional strategies for promoting development of abilities and/or understanding of how to use technology and/or mathematics. This finding is not much different to the one revealed when Kumar and Libidinsky analyzed K–12 Web-based STS instructional resources (Kumar & Libidinsky, 2000). According to Kumar and Libidinsky (2000), only 12% of analyzed STS Websites represented more that 25% of the STS criteria recommended by the NSES. The relevant findings imply that there is an urgent need for biological website designers to develop a wide range of websites with instructional strategies aligned with the NSES.

Biology Learning

In the context of learning, a major implication of the findings of this study is that instructional strategies of the analyzed websites are justified by cognitive learning theories. Hence, the web-based instructional offerings of the analyzed websites support active, constructive, goal-oriented learning that is linked to social context. This type of learning is meaningful and is likely to enhance academic achievement.

Specifically, the findings of the study imply that biological science websites with features aligned to the NSES can enhance biology learning. Students can use the findings to locate websites that comply to a great extent with the NSES. Such websites will foster a constructivist approach to learning. Thus, students will be channeled through an active, student-centered learning process.

Students who utilize websites that are compliant with the NSES are likely to improve their conceptual understanding of difficult biological science topics. These students are also likely to enhance their critical thinking and problem solving skills. An important implication of improved conceptual understanding, critical thinking, and problem solving skills is that students are likely to enhance their overall academic performance. In addition, students will be able to establish science, technology, and society relationships that have the potential to foster meaningful real-world, business-related applications. Instructional strategies that allow students to establish connections with real-world applications are commendable since science teaching is often disconnected from real-world applications (Kumar & Altschuld, 2003).

Development of Biological Science Websites

Both the significant and non-significant findings of this study imply that there is a need for development of websites with attributes that are closely aligned with the NSES. These findings may motivate biological science teachers to develop websites with content, instructional strategies, assessment methods, and other components that are closely aligned with the NSES. Possibly, the findings will provide insights for initiating collaboration between biology teachers and professional website designers to ensure that new biological science websites adhere closely to mandates that are stipulated by the NSES.

Website Designs

Findings of this study have direct implications for initializing improvements in biological science website designs. These findings have the potential to make website designers aware of cases of non-alignment of biological science website content, instructional strategies, and assessment methods with the NSES. This kind of awareness can motivate website designers to align content, instructional strategies, and assessment methods with the NSES. Basically, website designers can enhance the educational value of science websites by applying findings of this study to improve content, instructional strategies, and assessment methods of their website designs.

Web-assisted Education

This study has provided evidence that the biology content, instructional strategies, and assessment methods of 13.75% of the analyzed biological science websites were at least 85% aligned with the NSES for Grade 12 Life Science. Additional evidence indicated that the biology content, instructional strategies, and assessment methods of 40% of the analyzed websites were at least 50% aligned with the NSES for Grade 12 Life

Science. These positive findings have profound implications for using biological science websites to implement web-assisted science education. Science teachers can use specific findings of this study to inform students about websites that have excellent content, instructional strategies, and assessment methods aligned with NSES. On a global scale, educators and students can use data from this study to guide their selection of websites for enhancing web-assisted biological science education.

Scientific Literacy

Websites with content, instructional strategies, and assessment methods that are strongly aligned with NSES are powerful tools for helping students to achieve scientific literacy. Specifically, websites that comply with NSES for the Life Sciences can enable biology students to have meaningful experiences based on the scientific inquiry model of learning. These compliant websites expose students to resources that enhance the process of scientific inquiry. Also, these websites are laden with the potential to make students understand scientific concepts and other fundamental aspects of science. For example, students can gain understanding of the scientific method and become aware that science is an open-ended process.

One negative finding of this study is that content, instructional strategies, and assessment methods of 86.25% of the analyzed websites are less than 85% aligned with NSES. This finding implies that approximately 86% of biology websites lack many cognitively important attributes for fostering biological science education. Hence, these websites have limited potential to foster scientific literacy. The exposure of this information has direct implications for website designers who need to improve the educational quality of their products.

Applications to Other Disciplines

This study was limited to biological science websites for Grade 12 students. However, the findings have implications for improving the value of any educational website. Thus, the findings can be applied to a variety of other disciplines. For example, these findings can be used to initiate improvement of website designs, promote web-assisted education, and stimulate development of educational websites for a wide range of disciplines. Other examples of implications that relate to other disciplines are curriculum development and enhancement of professional development programs.

Specifically, the findings of the study have the potential to make website designers of any science discipline aware of the need to align website content, instructional strategies, and assessment methods with the NSES. Also, science teachers who identify cases of non-alignment of chemistry, physics, or any other science website with the NSES can urge website designers to comply with the standards. Science teachers who are aware of these findings will be able to inform students about both educationally valuable and deficient websites. This type of information can help students to become discriminatory about use of websites for educational purposes. Also, teachers can help students to use educationally deficient science websites with caution.

Curriculum Development

This study revealed that numerous features of the analyzed biological science websites are significantly aligned with the NSES in terms of content, instructional strategies, and assessment methods. One important implication of this finding is that biology teachers can utilize features of websites that align significantly with the NSES to develop their curriculum appropriately. The inclusion of NSES-aligned content, instructional strategies and assessment methods in biological science curricula can help students achieve desired learning outcomes. Curriculum development that involves the judicious incorporation of websites into biology curricula is particularly beneficial to high school and college teachers for allowing students to achieve mandated learning outcomes.

Findings of the study also exposed many cases in which content, instructional strategies, and assessment methods of biology websites are not significantly aligned with the NSES. These findings imply that website resources are inappropriate for use during curriculum implementation unless they comply with the NSES. The findings also imply that biology teachers need to analyze, evaluate, and select website resources carefully before utilizing them for curriculum implementation.

Professional Development

The findings of this study have implications for enhancing professional development of elementary, middle school, high school, and undergraduate science teachers. The study exposed numerous cases of biology website deficiencies in terms of non-alignment of content, instructional strategies, and assessment methods with the NSES. A fundamental implication of these specific findings is that in-service professional development programs are required to make science teachers at different levels of the educational hierarchy aware of deficiencies in websites. A related requirement of in-service professional development programs is helping teachers to overcome deficiencies in developing appropriate biological science websites for Grade 12 students.

A logical implication of the findings of this study is that professional development programs need to provide in-service teachers with opportunities for learning how to perform content analyses of websites. In addition, professional development programs should equip in-service biology teachers with skills for modifying and adapting deficient websites. Effective website modification and adaptation will facilitate use of a wide range of websites for effective biological science education. Another logical implication of the findings of this study is that science teacher education programs need to train pre-service teachers to analyze the attributes of websites properly in the context of the NSES.

Science teacher education programs also need to ensure that pre-service teachers have skills to utilize websites efficiently. An additional implication of the findings is that professional development programs need to promote the use of scaffolds among pre-service and in-service science teachers. This is an important implication because scaffolds have the potential to impose structure on web-based learning. Also, scaffolding is essential for ensuring that students derive maximum educational benefit from web-based resources.

Inclusion

Mandates of the NSES are intended to promote excellence in science education for all students. Therefore, K–12 science websites with attributes that are strongly aligned with the NSES have the potential to facilitate inclusion of all K–12 students. This implies that age, sex, culture, ethnicity, disabilities, socioeconomic status, interest, motivation or any other variation should not prevent K–12 students from attaining scientific literacy.

Major findings of this study are that the content, instructional strategies, and assessment methods of the analyzed websites are significantly aligned with criteria for alignment to the NSES. One specific finding is that 62.5% (50 out of 80) of the analyzed websites in the main study employed an inquiry-based instructional model for allowing learners to engage, explore, explain, extend, and/or evaluate. These findings imply that biological science websites can be used to implement student-centered learning models that have the potential to facilitate inclusion of diverse groups of Grade 12 biological science students. On a larger scale, the findings imply that science websites with attributes aligned to the NSES can facilitate inclusion of students at any level in the American educational system.

Conclusions

Several conclusions can be drawn based on the findings of this study.

1. The analyzed biological science websites have large quantities of their content that is significantly less than 85% aligned with the NSES.

2. The instructional strategies employed on the analyzed biological science websites are significantly less than 85% aligned with NSES.

3. The assessment methods utilized on the analyzed biological science websites are significantly less than 85% aligned with NSES.

4. Overall, 13.75 % of the analyzed biology websites are at least 85% aligned with the NSES. Thus, these websites are appropriate for promoting effective biological science learning and science education reform.

5. Of the sampled biological websites, 86.25% are less than 85% aligned with the NSES. Therefore, these websites have much of their content, instructional strategies and assessment methods that are not in compliance with the NSES. Additionally, many of these websites are not congruent with the inquiry model of learning, the constructivist theories of instruction or with other standards mandated by the NSES. This is unfortunate

because many students depend to a great extent on biological websites for enhancing learning.

The findings of this study have implications that relate to curriculum developers, professional development facilitators, teachers, and students. Websites with content, instructional strategies and assessment methods aligned to the NSES provide students with authentic web-based biological science resources. These types of resources have the potential to infuse inquiry and other national science education mandates into biology teaching and learning.

It is hoped that the findings of this study will serve as a stimulus for improving curriculum development and professional development of biology teachers in both high schools and colleges. Improved curriculum and biology teacher development has the ripple effect of improving biology teaching and the biological science learning process among students. Overall, it is hoped that the findings of this study will provide explicit information that can guide standards-based biology teaching and learning at both the high school and college levels of the educational hierarchy.

Recommendations

Content analyses of educational websites have the potential to reveal findings with powerful implications for the effective use of analyzed websites. Based on the limited evidence provided by this study, my main recommendation is for educational researchers to conduct several rigorous content analyses of biological science websites. The limited existing knowledge that relates to the compliance of biological science websites with the NSES provides additional rationale for researchers to perform future rigorous content analyses of biological science websites.

This study needs to be replicated with other biological science website samples that are selected by employing varied protocols. This is necessary because websites are ephemeral and new websites are developed frequently. There is also a need to replicate the study by using other analytical categories that are appropriate for the specific goals and scope of the research. The three categories of standards analyzed in this study are interrelated and they enhanced the research process. However, it is important to realize that other groups of categories exist for use during future research endeavors.

Future content analyses of biological science websites should utilize a modified and improved data collection instrument. The infusion of additional indicators of alignment with the NSES into the data collection instrument is one way of improving the instrument. This modification of the instrument is directly related to the analysis of other categories of the NSES.

The NSES serve as mandates for elementary, middle school as well as high school science teaching and learning. However the standards do not provide teachers with explicit recommendations or options for their implementation. Therefore, an additional recommendation is for science website content analyses to be done for each level of the educational hierarchy. This is an extremely important recommendation because website content analyses have implications for the implementation of the NSES at all educational levels. Also, these types of content analyses can have implications for systemic science education improvement.

A final recommendation is for trained educators to conduct qualitative as well as quantitative evaluations of biological science websites and other web-based science curricular resources. The implication of this recommendation is that evaluators will coerce science website designers to comply with the mandates of the NSES. It is important for evaluators to recognize that educational websites are not subject to regulation. Yet, they are extensively utilized by students and teachers as reform tools at all levels of the American educational system.

In *The Need for Comprehensive Evaluation in Science Education*, Kumar and Altschuld (2003) posited the implementation of evaluation as an integral part of science education reform. This implies an urgent need for evaluation of science websites because they serve pivotal roles in attempting to reform American science education. The reality is that efficient evaluation of all science education reform methods is absolutely essential for the promotion of excellence in science teaching and learning at all levels of the educational hierarchy.

It is hoped that the findings of this study and the recommendations for future research will serve as stimuli for the conduction of numerous other content analyses of science websites. On a larger scale, it is hoped that content analyses of science websites will contribute tangibly to K–12 science education reform. This type of systemic reform incorporating elementary, middle, and high school science should result in improvement of the overall quality of college level science education.

Appendixes

Appendix A

Data Collection Instrument

Data Collection Instrument

Data code #: _____________ Date Collected: _____________

Website Title: ____

URL:

Website Indicators of alignment to NSES	Yes	No
Criteria for analyzing biology content		
1. Are goals, objectives, or desired learning outcomes carefully defined (Bruner, 1977; Gagne, 1987)?		
2. Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science (NRC, 1990; Moore & Huber 2001)?		
3. Is the content appropriately sequenced to foster acquisition of fundamental biological science knowledge that will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?		
4. Does the content include historical case studies that relate to some of the basic scientific ideas (Bybee, 2002)?		

(table continues)

Data Collection Instrument *(continued)*

Criteria for analyzing instructional strategies		
1. Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate (Olson & Loucks-Horsley, 2000)?		
2. Do instructional strategies foster a constructivist approach to learning (Bednar et al., 1992; Gordon, 2008; Marlowe & Page, 2005; Shuell, 1986; Tobin et al., 1988; Windschitl, 2002)?		
3. Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues (Clark & Gorski, 2001)?		
4. Do instructional strategies promote real-world problem solving and/or applications (Bybee, 2002; Raizen, 1998)?		
5. Are learners engaged by scientifically oriented questions (Bodzin, 2005; NRC, 2000)?		
6. Are learners prompted to formulate their own questions or hypotheses that can be tested (Bodzin, 2005; NRC, 2000)?		
7. Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations (Olson & Loucks-Horsley, 2000)?		
8. Are learners encouraged to use evidence for drawing conclusions (Bodzin, 2005; NRC, 2000)?		
9. Are learners encouraged to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?		

(table continues)

Data Collection Instrument *(continued)*

10. Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations (Olson & Loucks-Horsley, 2000)?		
11. Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics (Olson & Loucks-Horsley, 2000)?		
12. Are illustrative examples provided to enhance understanding of facts and/or ideas in the context of a conceptual framework (Bruner, 1977; Bybee, 2002; Gagne, 1987)?		
13. Is emphasis placed on allowing students to apply and extend science learning to their daily lives (Pratt, 1998)?		
Criteria for analyzing assessment methods		
1. Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002; Linn & Hsi, 2000)?		
2. Are opportunities provided for learners to communicate and justify their proposed explanations of events (Bodzin, 2005; NRC, 2000)?		
3. Are learners required to use evidence for drawing and reporting conclusions (Bodzin, 2005; NRC, 2000)?		
4. Are learners required to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?		
Total # of questions = 21		

Appendix B

The Pilot Study

The Pilot Study

Procedure

The websites listed below were analyzed by using a custom designed data collection instrument. χ^2 tests were performed on the collected data to determine the statistical significance of differences of actual and expected frequencies of alignment of website biology content, instructional strategies and assessment methods with indicators of alignment to National Science Education Standards (NSES).

Websites Analyzed in the Pilot Study

1. http://nobelprize.org/educational_games/medicine/dna_double_helix/dnahelix.html
2. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/AnimalCells.html
3. http://pers.dadeschools.net/prodev/world_of_cells.htm
4. http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBooktransp.html#Table%20of%20Contents
5. http://www.tvdsb.on.ca/westmin/science/sbi3a1/Cells/Osmosis.htm
6. http://www.susanahalpine.com/anim/Life/endo.htm
7. http://www.stolaf.edu/people/giannini/biological%20anamations.html
8. http://www.biozone.com.au/biolinks/CELL_BIOLOGY.html#Top
9. http://www.amnh.org/education/resources/rfl/pdf/humanorigins_edguide.pdf
10. http://www.thegeneticscenter.com/chroman.htm
11. http://www.pbs.org/wgbh/evolution/educators/lessons/lesson4/act1.html
12. http://www.pbs.org/wgbh/evolution/change/family/
13. http://teachercenter.insidecancer.org/index.html

14. http://www.biochem4schools.org/default.htm
15. http://www.pbs.org/wgbh/nova/baby/divi_flash.html
16. http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/cell_division.html
17. http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/cell_division/CDCK/cdck.html
18. http://www.pathology.washington.edu/galleries/Cytogallery/main.php
19. http://www.rothamsted.ac.uk/notebook/courses/guide/
20. http://www.sumanasinc.com/webcontent/animations/content/stemcells_scnt.html

Instrumentation

The data collection instrument used in the pilot study was custom developed by the researcher using criteria based on the Web-based Inquiry for Learning Science instrument (Bodzin, 2005) and other pertinent information garnered from literature that was discussed in Chapter 2. This instrument asked 22 questions that are categorized into 3 distinct areas:

1. Biology content
2. Instructional strategies
3. Assessment methods

Criteria for analyzing biology content included 5 questions:

1. Does the content refer to a topic stipulated by the NSES for Grades 9-12 Life Science: The cell; Molecular basis of heredity; Biological evolution; Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms (NRC, 1996)?

2. Are goals, objectives, or desired learning outcomes carefully defined (Bruner, 1977)?

3. Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science (NRC, 1990; Moore & Huber 2001)?

4. Does the content foster acquisition of fundamental biological science knowledge that emphasizes major scientific ideas, which will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?

5. Does the content include historical case studies that relate to some of the basic scientific ideas (Bybee, 2002)?

Criteria for analyzing instructional strategies included 13 questions:

1. Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate (Olson & Loucks-Horsley, 2000)?

2. Do instructional strategies promote active learning (Bednar et al., 1992; Shuell, 1986; Tobin et al., 1988)?

3. Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues (Clark & Gorski, 2001)?

4. Do instructional strategies promote real-world problem solving and/or applications (Bybee, 2002; Raizen, 1998)?

5. Are learners engaged by scientifically oriented questions (Bodzin, 2005; NRC, 2000)?

6. Are learners prompted to formulate their own questions or hypotheses that can be tested (Bodzin, 2005; NRC, 2000)?

7. Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations (Olson & Loucks-Horsley, 2000)?

8. Are learners encouraged to use evidence for drawing conclusions (Bodzin, 2005; NRC, 2000)?

9. Are learners encouraged to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?

10. Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations (Olson & Loucks-Horsley, 2000)?

11. Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics (Olson & Loucks-Horsley, 2000)?

12. Do instructional strategies facilitate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002)?

13. Is emphasis placed on allowing students to apply and extend science learning to their daily lives (Pratt, 1998)?

Criteria for analyzing assessment methods included 4 questions:

1. Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002; Linn & Hsi, 2000)?

2. Are opportunities provided for learners to communicate and justify their proposed explanations of events (Bodzin, 2005; NRC, 2000)?

3. Are learners required to use evidence for drawing and reporting conclusions (Bodzin, 2005; NRC, 2000)?

4. Are learners required to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?

Data for each analyzed website were recorded on a data collection sheet that is included on the following two pages. “Yes” answers to 4 questions in the biology content category indicated the expected alignment of the website’s biology content with instrument- based indicators of alignment with the NSES that relate to biology content. “Yes” answers to 11 questions in the instructional strategies category indicated the expected alignment of the website’s instructional strategies with indicators of alignment with the NSES that relate to instructional strategies. “Yes” answers to all 3 questions in the assessment methods category indicated the expected alignment of the website’s assessment methods to the NSES that relate to assessment methods.

Pilot Study Results

Correlation of Percentage Interrater "Yes" Responses to Each Question

	% Yes Responses			
Analyzing biology content	Rater 1	Rater 2	Correlation	Significance
1. Does the content refer to a topic stipulated by the National Science Education Standards for Grades 9-12 Life Science: The cell; Molecular basis of heredity ; Biological evolution; Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms (NRC, 1996)?	100	100	Not computed	Not Applicable
2. Are goals, objectives, and desired learning outcomes carefully defined (Bruner, 1977)?	15	25	0.728	0.0001*
3. Does the content exist within a contextual framework that allows learners to develop understandings about the nature, philosophy, history, and/or relevance of science (NRC, 1990; Moore & Huber 2001)?	50	35	0.734	0.0001*
4. Does the content foster acquisition of fundamental biological science knowledge that emphasizes major scientific ideas, which will contribute to development of a strong conceptual framework in students (Bruner, 1977; Bybee, 2002; Deboer, 1991; NRC, 1990; NSTA, 1964; Rutherford & Ahlgren, 1989)?	100	100	Not computed	Not Applicable
5. Does the content include historical case studies that relate to some of the basic scientific ideas (Bybee, 2002)?	30	30	0.762	0.0001*

Note. * $p < 0.05$ (2-tailed)

Correlation of Percentage Interrater "Yes" Responses for the Instructional Category of the Data Collection Instrument

	% Yes Responses			
Analyzing instructional strategies	Rater 1	Rater 2	Correlation	Significance
1. Is an inquiry-based instructional model employed for allowing learners to engage, explore, explain, extend, and/or evaluate (Olson & Loucks-Horsley, 2000)?	65	55	0.881	0.0001*
2. Do instructional strategies promote active learning (Bednar et al., 1992; Shuell, 1986; Tobin et al., 1988)?	40	40	1.0	0.0001*
3. Do instructional strategies promote development of higher-order thinking skills that enable learners to use facts, figures, and/or formulas within the context of considering large conceptual issues (Clark & Gorski, 2001)?	30	35	0.892	0.0001*
4. Do instructional strategies promote real-world problem solving and/or applications (Bybee, 2002; Raizen, 1998)?	50	40	0.816	0.0001*
5. Are learners engaged by scientifically oriented questions (Bodzin, 2005; NRC, 2000)?	45	50	0.704	0.001*
6. Are learners prompted to formulate their own questions or hypotheses that can be tested (Bodzin, 2005; NRC, 2000)?	20	20	0.688	0.001*
7. Do instructional strategies foster development of abilities and/or understanding of how to design and conduct scientific investigations (Olson & Loucks-Horsley, 2000)?	20	15	0.840	0.0001*
8. Are learners encouraged to use evidence for drawing conclusions (Bodzin, 2005; NRC, 2000)?	35	35	1.0	0.0001*

(table continues)

(continued)

Analyzing instructional strategies	% Yes Responses Rater 1	Rater 2	Correlation	Significance
9. Are learners encouraged to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?	5	5	-0.053	0.826
10. Are opportunities provided for development of the cognitive skills associated with the formulation of scientific explanations (Olson & Loucks-Horsley, 2000)?	20	25	0.866	0.0001*
11. Do instructional strategies promote development of abilities and/or understanding of how to use technology and/or mathematics (Olson & Loucks-Horsley, 2000)?	20	25	0.866	0.0001*
12. Do instructional strategies facilitate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002)?	95	100	Not computed	Not Applicable
13. Is emphasis placed on allowing students to apply and extend science learning to their daily lives (Pratt, 1998)?	30	30	0.762	0.0001*

Note. * $p < 0.05$ (2-tailed)

Correlation of Percentage Interrater "Yes" Responses to Each Question Included in the Assessment Category of the Data Collection Instrument

	% Yes Responses			
Analyzing assessment methods	Rater 1	Rater 2	Correlation	Significance
1. Are prompts provided for learners to demonstrate understanding of facts and/or ideas in the context of a conceptual framework (Bybee, 2002; Linn & Hsi, 2000)?	30	30	0.882	0.0001*
2. Are opportunities provided for learners to communicate and justify their proposed explanations of events (Bodzin, 2005; NRC, 2000)?	15	15	1.0	0.0001*
3. Are learners required to use evidence for drawing and reporting conclusions (Bodzin, 2005; NRC, 2000)?	30	30	1.0	0.0001*
4. Are learners required to evaluate their conclusions in light of alternative conclusions (Bodzin, 2005; NRC, 2000)?	5	10	0.688	0.001*

Note. * $p < 0.05$ (2-tailed)

Overall Categorical χ^2 *Results*

Item Category	% Yes Responses		% No Responses		χ^2 Values		df	*p* Values	
	Rater 1	Rater 2	Rater 1	Rater 2	Rater 1	Rater 2		Rater 1	Rater 2
Biology content	59.00	58.00	41.00	42.00	27.56	30.25	1	0.001*	0.001*
Instructional strategies	36.54	36.54	63.46	63.46	315.54	238.88	1	0.001*	0.001*
Assessment methods	20.00	21.25	80.00	78.75	135.00	123.27	1	0.001*	0.001*
Overall	58.00	38.61	42.00	61.39	450.81	85.00	1	0.001*	0.001*

Note. * $p < 0.05$ (2-tailed)

Interrater χ^2 and p Values for Each Analyzed Website

Website	χ^2 Rater 1	Chi-square Rater 2	*p* Rater1	*P* Rater2
1	12.68	9.32	0.001*	0.001*
2	37.27	50.73	0.001*	0.001*
3	37.27	37.27	0.001*	0.001*
4	43.74	43.74	0.001*	0.001*
5	43.74	50.73	0.001*	0.001*
6	43.74	43.74	0.001*	0.001*
7	43.74	43.74	0.001*	0.001*
8	76.05	76.05	0.001*	0.001*
9	6.47	0.26	0.01*	0.61
10	31.32	31.32	0.001*	0.001*
11	9.32	6.47	0.001*	0.01*
12	0.26	0.26	0.61	0.61
13	16.56	16.56	0.001*	0.001*
14	2.33	2.33	0.13	0.13
15	25.88	43.74	0.001*	0.001*
16	4.14	6.47	0.04*	0.01*
17	12.68	9.32	0.001*	0.001*
18	50.73	50.73	0.001*	0.001*
19	37.27	37.27	0.001*	0.001*
20	25.88	25.88	0.001*	0.001*

Note. * $p < 0.05$ (2-tailed)

Discussion

The pilot study findings indicate that the content, instructional strategies, and assessment methods of 85 % of the analyzed biology websites were less than 85% aligned with the NSES. Hence, the findings imply that the content, instructional strategies, and assessment methods of 85 % of the sampled biological science websites are not congruent with the inquiry model of learning, the constructivist theories of instruction, or with other standards mandated by the NSES. A further implication of this finding is that 85 % of biology websites lack the potential to facilitate meaningful learning and science education reform. However, the instructional strategies of websites that were most closely aligned with the NSES emphasized a broad view of science content, student-centered instruction, a wide range of assessment procedures, student thinking, application of science knowledge and understanding, and learning for career awareness and exploration.

This pilot study has provided evidence that the biology content, instructional strategies, and assessment methods of 85 % of the analyzed biological science websites are less than 85% aligned to the NSES for Grade 12 Life Science. These findings have profound implications for the effectiveness and usefulness of biological science websites for Internet-based science education. Additionally, the findings have direct implications for improving the educational value of science websites. Specifically, these findings have the potential to alert the designers of science websites and science teachers about the instances of non-alignment of biological science website content, instructional strategies, and assessment methods with the NSES. Science teachers who develop awareness of deficiencies in biological science websites can urge website designers to comply with

NSES. In addition, science teachers can direct students to websites that have content, instructional strategies, and assessment methods aligned with NSES. Science teachers can also inform students about the deficiencies in websites and they can help their students to use deficient websites with caution.

Recommendations

The findings of this pilot study are based on an extremely small sample of websites (n = 20). Consequently, I recommend future conduction of large scale content analyses of biological science websites. The limited existing knowledge that relates to the compliance of biological science websites with the NSES provides additional rationale for future rigorous content analyses of biological science websites. Information based on the limited evidence provided by this pilot study should not be widely disseminated until numerous other content analyses of biological science websites are conducted.

Appendix C

Websites Analyzed in the Main Study

Websites Analyzed in the Main Study

1. http://www.mos.org/educators
2. http://teach.genetics.utah.edu/content/begin/cells/
3. http://www.kenneth-eward.com/cvp/cvpindex.html
4. http://ginaotto.com/sciencesites.html
5. http://nsdl.org/collection/general-science/
6. http://www.pbs.org/wgbh/nova/teachers/activities/0301_02_nsn.html
7. http://www.mysciencebox.org/book/export/html/320
8. http://www.teachersdomain.org/resource/tdc02.sci.life.cell.lp_prosyn/
9. http://eelink.net/pages/Student+Programs
10. http://www1.smsd.org/staffdev/high/science.htm
11. http://www.genome.gov/Pages/Education/AllAbouttheHumanGenomeProject/GuidetoYourGenome07.pdf
12. http://www.clickandlearn.org/Bio/bio_links.htm
13. http://www.pbs.org/wgbh/nova/genome/manipulate2.html
14. http://42explore.com/genes.htm
15. http://www.biotech.iastate.edu/IA_biotech_educator/Mar_1999.html
16. http://www.mariemontschools.org/halsall/dnalinks.htm
17. http://www.umass.edu/molvis/tutorials/dna/
18. http://www.learner.org/interactives/dna/index.html
19. http://www.dnai.org/lesson/go/1035/
20. http://biop.ox.ac.uk/www/mol_of_life/index.html

21. http://www.cellsalive.com/

22. http://www.stemtransitions.org/clear-stem.php

23. http://www.thirteen.org/h2o/educators_lesson5.html

24. http://www.cellbio.com/education.html

25. http://www.biologie.uni-hamburg.de/b-online/e19/19.htm

26. http://library.thinkquest.org/C004535/introduction.html

27. http://www.insidecancer.org/

28. http://ghr.nlm.nih.gov/

29. http://science.education.nih.gov/supplements/nih1/genetic/activities/activity2.htm

30. http://science.education.nih.gov/customers.nsf/HSCancer?OpenForm

31. http://www.ncbi.nlm.nih.gov/About/primer/genetics_cell.html

32. http://www.amnh.org/education/resources/rfl/pdf/humanorigins_edguide.pdf

33. http://nsdl.org/search/?n=10&q=&grade%5B%5D=L4&s=0&verb=Search

34. http://www.centreofthecell.org/

35. http://www.actionbioscience.org/

36. http://www.biozone.co.nz/links.html

37. http://www.getbodysmart.com/

38. http://www.johnkyrk.com/

39. http://www.tvdsb.on.ca/westmin/science/sbi3a1/cells/cells.htm

40. http://www.darwinfoundation.org/

41. http://www.hhmi.org/biointeractive/

42. http://www.biology.arizona.edu/

43. http://www.hhmi.org/genetictrail/ http://www.darwinfoundation.org/

44. http://darwin-online.org.uk/

45. http://www.dnai.org/

46. http://www.dnaftb.org/

47. http://www.pbs.org/wgbh/evolution/index.html

48. http://www.activescience-gsk.com/miniweb/content/cloning/evolution.htm

49. http://www.teachersdomain.org/resource/tdc02.sci.life.evo.allinthefamily/

50. http://www.thetech.org/genetics/

51. http://www.sciencemuseum.org.uk/exhibitions/genes/index.asp

52. http://www.pbs.org/wgbh/nova/genome/

53. http://www.genome.gov/

54. http://www.ornl.gov/sci/techresources/human_genome/education/education.shtml

55. http://genomicsgtl.energy.gov/

56. http://www.yourgenome.org/

57. http://www.ygyh.org/

58. http://www.koshland-science-museum.org/exhibitdna/index.jsp

59. http://www.nsf.gov/news/overviews/biology/interactive.jsp

60. http://www.free.ed.gov/resource.cfm?resource_id=1990&subject_id=252&toplvl=54

61. http://evolution.berkeley.edu/

62. http://www.usoe.k12.ut.us/curr/science/sciber00/8th/energy/sciber/intro.htm

63. http://www.sp.uconn.edu/~terry/images/anim/ATPmito.html

64. http://www.istemnetwork.org/resource/detail.cfm?resourceid=164

65. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html#Biochemistry

66. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html#CellBiology

67. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html#DNA

68. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html#Evolution

69. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html#PlantBiology

70. http://www.biologymad.com/

71. http://www.science.smith.edu/departments/Biology/Bio231/glycolysis.html

72. http://vcell.ndsu.nodak.edu/animations/etc/movie.htm

73. http://www.biologyinmotion.com/atp/index.html

74. http://www-saps.plantsci.cam.ac.uk/pubphoto.htm

75. http://bioenergy.asu.edu/photosyn/education/learn.html

76. http://biology.clc.uc.edu/courses/bio104/photosyn.htm

77. http://www.abpischools.org.uk/res/coResourceImport/resources04/cancer/index.cfm

78. http://www.berkshiremuseum.org/programs/youth/1_reptiles_evolution.html

79. http://www.biology.arizona.edu/human_bio/human_bio.html

80. http://www.okstate.edu/artsci/SPMO/activities.htm

Appendix D

% “Yes” Responses, Website Ranks, and χ^2 Results for Indicators of Website Alignment with the NSES

% "Yes" Responses, Website Ranks, and χ^2 Results for Indicators of Website Alignment with the NSES

Website	Yes Responses	Rank	χ^2	*p* Value
1	6	5	56.00	0.001*
2	9	8	31.50	0.001*
3	5	4	65.72	0.001*
4	20	19	1.56	0.21
5	17	16	0.39	0.53
6	12	11	14.00	0.001*
7	20	19	1.56	0.21
8	14	13	6.22	0.01*
9	16	15	1.56	0.21
10	18	17	0.00	1.00
11	6	5	56.00	0.001*
12	8	7	38.89	0.001*
13	8	7	38.89	0.001*
14	9	8	31.50	0.001*
15	9	8	31.50	0.001*
16	8	7	38.89	0.001*
17	8	7	38.89	0.001*
18	14	13	6.22	0.01*
19	15	14	3.50	0.06
20	12	11	14.00	0.001*
21	6	5	56.00	0.001*
22	14	13	6.22	0.01*
23	20	19	1.56	0.21
24	21	20	3.50	0.06
25	4	3	76.22	0.001*
26	5	4	65.72	0.001*
27	3	2	87.50	0.001*
28	13	12	9.72	0.001*
29	13	12	9.72	0.001*
30	20	19	1.56	0.21
31	9	8	31.50	0.001*
32	11	10	19.06	0.001*

(table continues)

% "Yes" Responses, Website Ranks, and χ^2 Results for Indicators of Website Alignment with the NSES (continued)

Website	Yes Responses	Rank	χ^2	*p* Value
33	12	11	14.00	0.001*
34	10	9	24.89	0.001*
35	7	6	47.06	0.001*
36	14	13	6.22	0.01*
37	5	4	65.72	0.001*
38	5	4	65.72	0.001*
39	6	5	56.00	0.001*
40	8	7	38.89	0.001*
41	19	18	0.39	0.53
42	17	16	0.39	0.53
43	14	13	6.22	0.01*
44	9	8	31.50	0.001*
45	13	12	9.72	0.001*
46	10	9	24.89	0.001*
47	12	11	14.00	0.001*
48	4	3	76.22	0.001*
49	18	17	0.00	1.00
50	13	12	9.72	0.001*
51	8	7	38.89	0.001*
5	11	10	19.06	0.001*

2				
53	7	6	47.06	0.001*
54	5	4	65.72	0.001*
55	4	3	76.22	0.001*
56	7	6	47.06	0.001*
57	10	9	24.89	0.001*
58	15	14	3.50	0.06
59	3	2	87.50	0.001*
60	7	6	47.06	0.001*
61	8	7	38.89	0.001*
62	17	16	0.39	0.53
63	3	2	87.50	0.001*
64	11	10	19.06	0.001*
65	3	2	87.50	0.001*
66	3	2	87.50	0.001*
67	4	3	76.22	0.001*
68	8	7	38.89	0.001*
69	4	3	76.22	0.001*

(table continues)

% "Yes" Responses, Website Ranks, and χ^2 Results for Indicators of Website Alignment with the NSES (continued)

Website	Yes Responses	Rank	χ^2	*p* Value
70	4	3	76.22	0.001*
71	3	2	87.50	0.001*
72	2	1	99.56	0.001*
73	4	3	76.22	0.001*
74	11	10	19.06	0.001*
75	3	2	87.50	0.001*
76	2	1	99.56	0.001*
77	7	6	47.06	0.001*
78	6	5	56.00	0.001*
79	11	10	19.06	0.001*
80	6	5	56.00	0.001*

Note. * $p < 0.05$ (2-tailed) *The minimum acceptable # of yes responses is 17 (85%)*

1 denotes the lowest rank or most weakly aligned with the NSES

20 denotes the highest rank or most strongly aligned with the NSES

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